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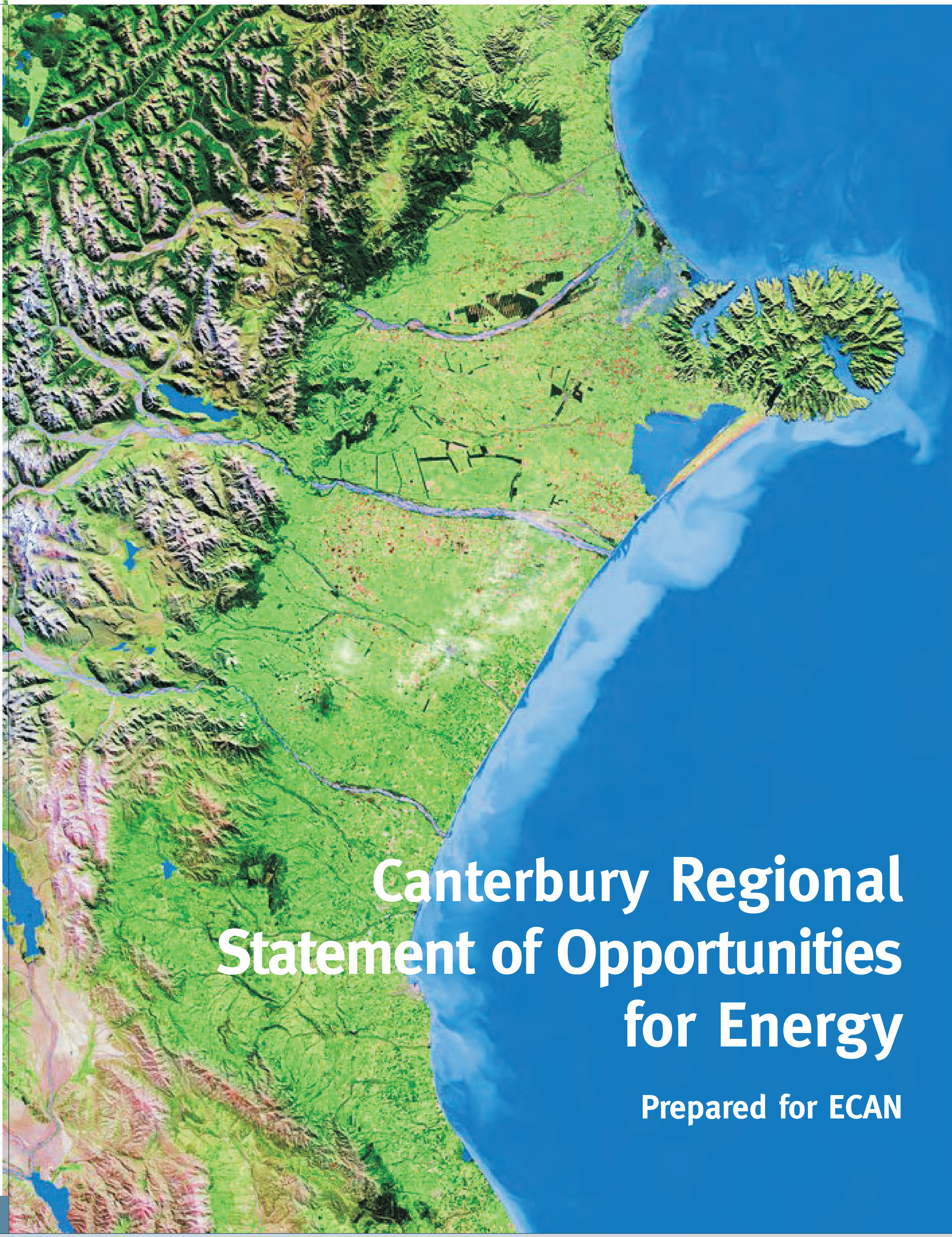

# Canterbury Regional Statement of Opportunities for Energy

**Prepared for ECAN**

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# 1 INTRODUCTION

> *'Infinite growth on a finite planet is an impossibility.'*
>
> E F Schumacher (1973)

The key objectives of this *Draft Regional Statement of Opportunities for Energy in Canterbury* (RSOO) are to provide background and support material that will assist with the development of the Canterbury Regional Energy Strategy by:

a) communicating the range of possibilities for regional energy investment (supply-side opportunities); and

b) communicating demand-side opportunities (e.g. energy demand reduction or demonstration projects).

This regional statement of opportunities for energy (RSOO) in Canterbury is primarily a desk-top initiative of existing available information as applied to the Canterbury Region. This is a starting point to provide an initial overview of the energy options in the Canterbury Region that can be built upon in the development of a greater Regional Energy Strategy with stakeholder and community involvement.

Environment Canterbury's Energy Strategy (ECES) released as a draft in December 2008 has attempted to define the current and emerging issues relating to the provision of a secure, reliable and affordable energy supply for the region, an energy supply that is anticipated, ultimately, to be sustainable. The ECES will feed into the development of a stakeholder-driven energy regional strategy (CRES). It will be complementary to existing regional strategies particularly Christchurch City's Sustainable Energy Strategy (2008-2018), (seeking similar outcomes leading to a sustainable Canterbury community), as well as national strategies such as the New Zealand Energy Strategy, New Zealand Energy Efficiency & Conservation Strategy, and climate change policy (in particular, the role of the Emissions Trading Scheme), released in 2007. It will also be complementary to the Energy Sustainability Plan - Creating Competitive Advantage for the Waitaki Community, CAENZ, December 2008.

It is intended that similar current and future district and TLA plans will draw upon and be complementary to the CRES.

The National-led Government believes a refocusing of the New Zealand Energy Strategy is required. The new strategy will focus on security of supply, affordability, and environmental responsibility, with the overriding goal of maximising economic growth. The Government is currently considering the best way of carrying out the update of the Energy Strategy and the Minister will make further announcements about this in the coming weeks.

The relationship of this Regional Statement of Opportunities (RSOO) report, to Regional policy and planning is highlighted in Table 1.1 Responses to pressures on energy.

A schematic of how a Regional Energy Study may be implemented through statutory and non-statutory influence, including this RSOO, is shown in Figure 1.1.

Canterbury is one of the fastest growing regions in New Zealand. Regional growth puts pressure on the systems that supply the region's growing energy demands for: transport, agriculture, the power industry, manufacturing, domestic usage and business.

Each region has local energy usage trends, and continued reliance on centralised planning is not seen as the only way forward. A new approach to planning that takes better account of regional opportunities, industry capacity and local needs, can focus on creating local opportunities and delivering an overall improved energy supply system.

## 1.1 CRESP project (Stage 1 completed in April 2007)

The CRESP project (Stage 1 completed in April 2007) aimed to develop and outline such a process. The Stage 1 analysis helped define the strategic objectives that might inform the planning process and also identified a number of core issues for further investigation and

| Issue | Investigations & Monitoring | Policy & Planning | Advocating & Education |
|---|---|---|---|
| Sustainable energy resources | Identifi cation of region's resources | Canterbury Regional Energy Strategy<br>- develop with stakeholders a Regional Statement of Opportunities as a basis for future planning<br>- benefi is derived from renewable energy | |
| Increase in energy demand | Biennial regional energy survey | Canterbury Regional Energy Strategy<br>- eight priority areas for action including existing homes, electricity transmission and biofuels/biomass | |
| Dependency on imported transport fuels | Investigation reports | Long-Term Council Community Plan<br>- develop a policy response to projected future fuel price increases and shortages | |
| Lack of effective regional energy planning framework | | Canterbury Regional Energy Strategy<br>- develop with stakeholders a Regional Statement of Opportunities as a basis for future planning | Community consultation |
| Transmission constraints | | Regional Policy Statement<br>- encourage a reliable and resilient national electricity network | |
| Limited local generation opportunities | | Regional Policy Statement<br>- encourage efficient, reliable and resilient electricity within Canterbury | |
| Regional winter electricity security | | Regional Policy Statement<br>- develop with stakeholders a Regional Statement of Opportunities as a basis for future planning | |
| Conflict with water and air quality planning | Monitoring of summertime electricity use and space heating end use | Natural Resources Regional Plan<br>- review PNRRP Chapters 3 and 5 to identify potential for energy conflicts | |
| Development of energy infrastructure | Monitoring for environmental and social effects | Regional Policy Statement<br>- integration of infrastructure with land use | |
| Energy efficiency | | Regional Policy Statement<br>- efficiency of end use of energy | Advocate for and encourage best practice |
| Public awareness and consumer responsiveness | | Long-Term Council Community Plan | Publicity material |

*Table 1.1 Responses to pressures on energy*
*(Source: Canterbury Regional Environment Report 2008, Table 9.2)*

analysis. These core areas are grouped into either Regional, Industry or Local contexts.

### 1.1.1 Regional

- The Canterbury region has a higher than average dependency on major transmission and supply system security.
- Emerging environmental issues could impact future energy demand and future energy supply opportunities, e.g. water scarcity/competition, air quality/fuel substitution choices, lack of reticulated gas.
- The region has resource potential to achieve greater energy diversity and less import dependency, but their economic timing and delivery remain uncertain.
- Growth in tourism, business services and export food processing has contributed to a large growth in transport related costs and the energy import dependency. Future growth could be aligned with alternative energy supply options – e.g. bio-fuels and hybrid vehicles.

### 1.1.2 Electricity Industry

- Supply chain risk needs to be reduced by aligning industry planning assumptions including common time period outlook, asset age risk, aligning different planning frameworks and acknowledging non-aligned incentives or asymmetric risks. Supply chain risk needs to be reduced: Industry planning assumptions need to be aligned with common time period outlook and

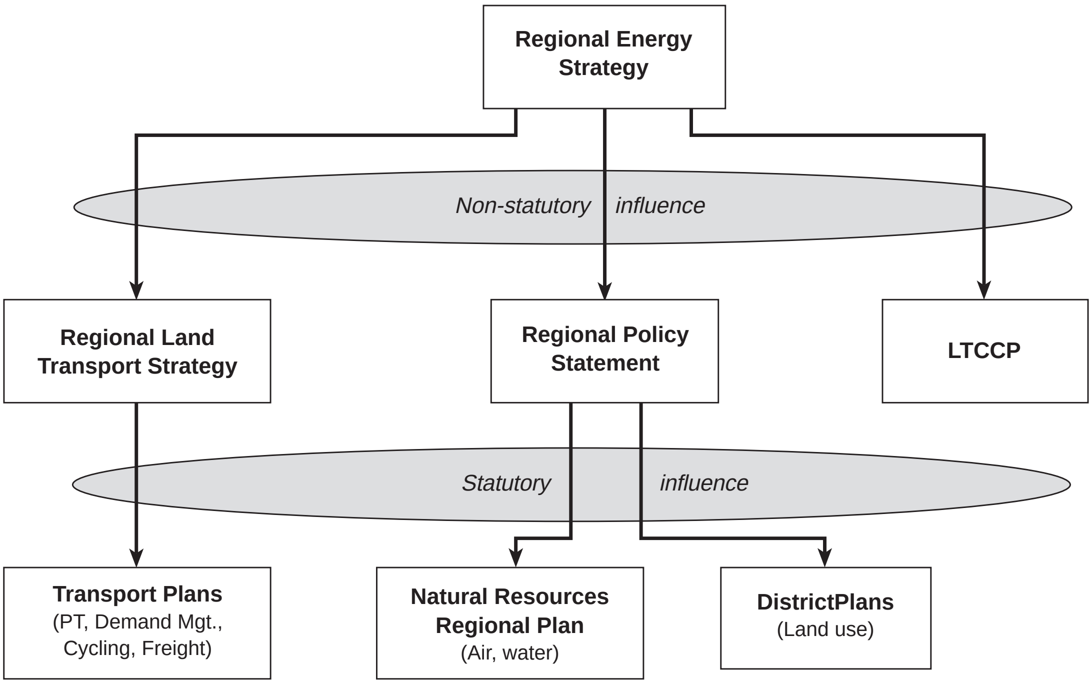


*Figure 1.1: Schematic of how a Regional Energy Strategy could be implemented through statutory planning mechanisms. (Source: Identifying the Linkages between Energy Policy and other ECAN Policy Portfolios, CAENZ, June 2008)*

asset age risk. Different planning frameworks need to be aligned. Incentives and asymmetric risks that are non-aligned need to be acknowledged.

- The current market response framework encourages shorter planning and investment cycles that shifts reliability related risk to the consumer, increases timing/delivery risks for investors, and makes planning lead times difficult to determine.
- Incremental investment is valid but should not compromise the opportunities for realising key strategic regional benefits;
- Incorporating a wider risk and vulnerabilities assessment
- Understanding situations where investing too late is worse than too early
- Adopting rules or guidelines vs. commercial drivers.

### 1.1.3 Local

South Island Reserve Energy Options that should be examined further:

- Regional winter market reserves risks
- Benefits of economies of scale vs. distributed solutions
- Low South Island thermal reserves –value of system diversity
- The vulnerabilities from not having "N-g-1" network security in Canterbury.

There are opportunities for more integrated energy supply developments including irrigation/hydro developments, waste to energy projects (with carbon credits), further regional distributed generation, smart and fuel substitutions.

The Region has some potential longer term strategic energy assets including on and offshore gas prospects and wind power. Stage 1 of CRESP has identified the above areas of interest for further study as they all have implications that directly affect both national and regional planning. Further analysis of issues and comparisons between alternatives is required in order to further develop a new regional planning framework.

## 1.2 New Zealand's Position from a Global Perspective

Canterbury plays a significant role in national energy supply. Its development has always been greatly influenced by national needs which in turn are driven by international issues. Consideration of global energy issues therefore provides the reference frame for what trends and technology we might expect to see in New Zealand. These matters are of great interest to the National Grid Operator, Transpower, who are currently conducting a scenario planning exercise for the purpose of updating their long term Grid Development Strategy: Transmission 2040. The following information has been extracted from their consultation material.

In some respects Transpower's document is an indication that issues like global warming and peak oil have now become mainstreamed into Government and institutional thinking. Four future scenarios of the future have been developed to test sensitivity issues and the robustness of energy supply development plans.

**Scenario 1 – New Norway**

***The global scene***

An international agreement on combating climate change is made. An ambitious goal is set – stabilisation at 450 ppm (parts per million) concentration of $CO_2$ in the atmosphere. National and regional emissions trading schemes are linked and over time, one global market for carbon is established. Increased unrest in the Middle East plus cost of carbon makes energy prices soar and with that inflation. That increases the cost of oil substitutes further. World economy keeps a reasonable growth driven by China and India. As a result, the oil price is high. With many countries shifting from coal to gas to reduce emissions, demand for gas is high – especially if sourced outside the Middle East. As a result, the LNG price follows the oil price all the way up to the new level.

***The local scene***

The first decade of the new millennium ends with a big prize for New Zealand. At first, a medium-sized gas field is found near Taranaki keeping supply secured well into the 2020s. Then, in early 2010 a large oil and gas field off the coast of the South Island is discovered. The evaluation of the discovery takes a couple of years. Apart from a significant amount of oil, there is more gas than in the Maui gas field when found. In 2018, the first export shipment of LNG is made to the Chinese market. The economy is booming due to the discovery of hydrocarbons and immigration increases. More arrive as climate change refugees find living in their former countries becoming unbearable. To limit the demand growth in the booming economy, environmental taxes are introduced. Still, demand is growing fast, fuelled by a major transformation of the transport sector to electric vehicles. Demand is met by generation placed where most economic - typically larger renewable installations, including marine energy. As a spin-off from the offshore industry, New Zealand is established as a world leader in harnessing wave energy.

**Scenario 2 – Crisis recalled**

***The global scene***

After a turbulent time in 2005-2012, oil prices stabilize in a new price band around US$55-65/bbl assisted in part, by technological improvements in extracting oil from unconventional sources. LNG prices are similarly low. The cost of carbon is close to zero as a disruptive technology innovation that cheaply removes carbon from the atmosphere. (It could also be seen as a scenario where due to a lack of international agreement on climate change, no country is taking significant action, or a scenario where it turns out climate change is not happening). Large and timely investments in mineral exploration and extraction keep inflation down. As a result of this, the lower oil price and the limited carbon cost, the global economy is growing. Every year 100 million people worldwide are entering the middle class, demanding, amongst other things, more food.

***The local scene***

The global demand for dairy products, meat and fish is a major driver for the New Zealand economy. Tourism is also doing well. In comparison with the rest of the world, New Zealand is not outperforming, so immigration levels stay at the historical average. With little constraints on the use of coal, energy prices are relatively low. As a result of the high GDP growth and low prices, demand is growing at a high rate. Small micro-cogeneration units become popular, first in commercial settings but later on in households as well. They supply space and hot water heating and generate electricity as well. Typically, a Stirling engine is used but later on Fuel Cells capable of running on reticulated natural gas is taking over as the preferred technology. Otherwise demand is largely met by thermal power plants built near Auckland and tidal turbines near Auckland and Wellington.

**Scenario 3 – Fragmented world**

*The global scene*

Tensions in the Middle East, and Russia's quest to return to its former might, result in energy security of supply being jeopardized world-wide. With the financial crisis that started back in 2007 still dragging on, most countries try to save themselves rather than cooperate on solving the issues. The major countries scramble to secure their energy supplies with most prospective oil and LNG projects being taken by high-bidding countries sometimes backed with military threats. The global economy is growing slowly - hampered by the import tax barriers being set up to protect national industry in many countries. As a result, oil demand is not growing as fast - and supply can keep up with demand. Carbon costs are moderate – with little international agreement on doing anything serious though it is clear that the climate is changing rapidly. Radical environmentalists start attacking oil and gas installations worldwide - including shipping of oil and LNG.

*The local scene*

Enough natural gas is found to meet local demand though the price closely matches the international LNG price. Methanex decides to close down its operations in New Zealand for good and as a result there is extra gas available for electricity generation. This is used by Combined Cycle Gas Turbines (CCGTs) in Taranaki with the $CO_2$ being extracted and stored in oil gas fields offshore Taranaki. Building a LNG terminal is considered uneconomic with the lack of LNG available for longer term contracts. A new set of "Think Big" projects are initiated to assist the economy and increase the security of supply. The projects include major hydro developments along the Clutha river and utilisation of the South Island lignite reserve.

**Scenario 4 – Green communities**

*The global scene*

If weather was considered extreme in the beginning of the millennium, it got even worse in the second decade. Clear signs of positive feedback (self-accelerating climate change) were the driver behind an international agreement of stabilising the level of $CO_2$ in the atmosphere at 450 ppm. LNG becomes popular in countries that traditionally had used coal for power generation as switching to gas was among the cheapest ways of reducing emissions. Biofuels from sea algae becomes an important source for transport fuels and results in a rather low penetration of electric vehicles.

*The local scene*

The New Zealand economy is taking a hit due to continuing global consumer concern over 'food miles'. Tourism also drops as international airlines start to bear the cost of carbon emissions as well. GDP growth is lower than the OECD average and immigration numbers are only kept up by climate change refugees, which see New Zealand as one of the last places to be severely affected by climate change. No LNG terminal is built, partly due to local opposition dragging out the resource consent lodged in 2009, but also because of LNG prices in combination with the carbon price would make it uneconomic. Instead, New Zealand embarks of a road of conservation and local generation, the latter assisted by the price of solar photo voltaic panels coming down rapidly.

## Scenario observations and uncertainties

An observation on the above scenarios is that Scenarios 1 and 2 are optimistically relying on hope i.e. we will be saved by a new energy discovery or technology will solve our problems. Scenarios 3 and 4 are not only more probable based on today's position but their consequences are more of an issue for those planning risk management in more adverse conditions. They necessarily will require the biggest change to the status quo. The actualisation of one planning scenario verses another is affected by the critical uncertainties associated with their drivers. Transpower has identified the following critical uncertainities:

- **International Fuel Price.** New Zealand is quite dependent on imported fuel and is therefore exposed to pricing risk as it competes for supply. Interestingly, security of supply is not considered critical even though we have just faced a dry year. In a dry year it is the pricing risk that is the dominant issue and not the direct lack of water or generation (the rivers have never stopped flowing and the lights have not been switched off as they were in the 1950's).

  Also of interest is that energy demand is not considered a critical uncertainty. There is no shortage of energy supply options (as long as the sun shines), the main issue is which option is the next least cost for meeting demand in terms of the costs we choose to recognise. In the absence of other costs like carbon and climate change considerations, New Zealand has had plenty of options for meeting electricity demand without the need to consider efficiency and any conservation options i.e. decisions have been confined to what large generation and transmission projects will be built where and when.
- **Cost of Carbon.** In New Zealand the long run marginal cost of new generation is so close between different types of technologies, that even moderate changes in fuel or carbon costs can change the technology most economic to build. The role of gas in our energy supply system effectively means that New Zealand is a low carbon economy relative to others with a high dependence on coal. Europe for example has been migrating from coal to gas for some time now.
- **Government Energy Policy.** This is clearly a direct intervention with a proven track record of being a wild card as governments are changed and respond to public opinion.
- **Climate Change.** New Zealand being an export based economy remote from its markets is sensitive to its customer's attitude towards such issues.
- **New Technology.** This is a cost stack issue i.e. not whether there are new technologies but which ones will prove to be the most cost effective, developed the quickest, and adopted by the trend setting economies.
- **Resource Planning Requirements (RMA)**. The RMA in many ways is a hurdle to the large scale core infrastructure developments of the past which clearly aren't going to meet sustainability into the future. It acts to change the cost stack in favour of smaller, more incremental and localised developments.

  New Zealand infrastructure providers have been slow to adapt to the legislation resulting in infrastructure getting older and being driven harder. The required change is resisted by those with large investments locked into the status quo i.e. new more efficient technology as measured by new cost/sustainability considerations are competitors to their existing business and devalue their investments. One could argue that the uncertainty created by the RMA is that while these investors continue to push proposals that don't meet expectations on environmental and sustainability issues the alternatives are not forth coming because they are not able to compete on an equal basis.

Transpower's document also identifies urbanisation, NIMBYism (not in my backyard), and global warming as global trends likely to be "imported" into New Zealand. With regards to this report it is noted that city-dominated politics and national perspective diverges with provincial communities on some of these issues.

## 1.3 Demographics

### New Zealand Population

A projection (medium series) for New Zealand up to 2051 as shown in Figure 1.2 indicates population levelling at 4.7 million people in the year 2036. There are significantly different projections depending on fertility, mortality and migration.

### Regional Population

Population change projections show significant variations between the regions as shown in Figure 1.4. Some regions are projected to reduce in population in the period 2006 to 2031. For the Canterbury region there are selected population and other statistics for each of the 10 Councils, shown in Table 1.2. Population growth has been uneven and is projected to continue to be uneven across the Canterbury region. Historical unemployment rates are

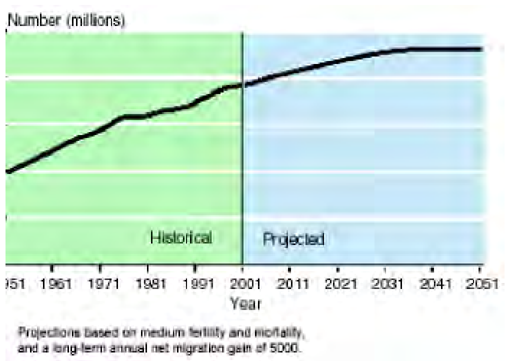


*Figure 1.2: New Zealand Population (Source: Statistics New Zealand)*


*Figure 1.3: Map of the Canterbury Region showing council boundaries*

lowest in the councils with the least density of population (people/km²), and range between 1.1% for Mackenzie and 3.0% for Christchurch. A map of the Canterbury region showimg council boundaries is shown in Figure 1.3.

## Estimated and Projected Population – Canterbury Region

According to the medium series of the 2006-base sub-national population projections (released December 2007), 12 of New Zealand's 16 regions and 40 of 73 territorial authority areas are projected to have more residents in 2031 than in 2006. However, population growth will slow over the projection period in all areas. Demographic projections should not be confused with economic forecasts. Changes in the number of people, families and households do not necessarily relate to the social and economic well-being of an area. The number of people, families and households may change

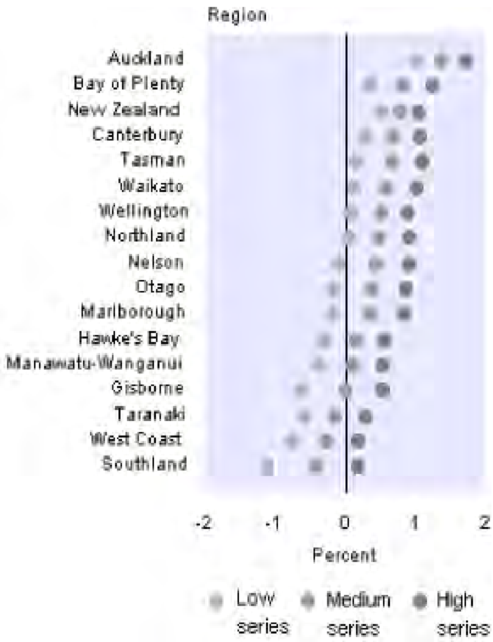


*Figure 1.4: Projected Average Annual Population Change, Regional Council areas, 2006-2031 (Source: Statistics New Zealand)*

independently of local economic factors.

Population growth in the Canterbury Region has been 8.4% for the 2001 to 2006 period. Figure 1.5 shows the projected population in the Canterbury region with a continuing growth at a slower rate, with three widely different projections.

The increase in New Zealand's population from three to four million was due mainly to natural increase, an excess of births over deaths, with little gain from migration.

## Projected Population and Household Change – Canterbury Region

The number of occupied dwellings increased by approximately 14,000 with the largest growth rate occurring in the Waimakariri and Selwyn Districts. for the 2001 to 2006 period. Although houses are being built, this may not translate into more people residing in an area. This could be due to such factors as fewer people per household on average, the building of holiday homes, or new buildings replacing demolished houses. Projected reduction applies to some council areas within Canterbury. For the whole of the Canterbury region these changes (for medium series) are shown in Figure 1.6.

*Table 1.2: 2006 Population Canterbury Region Selected Statistics*

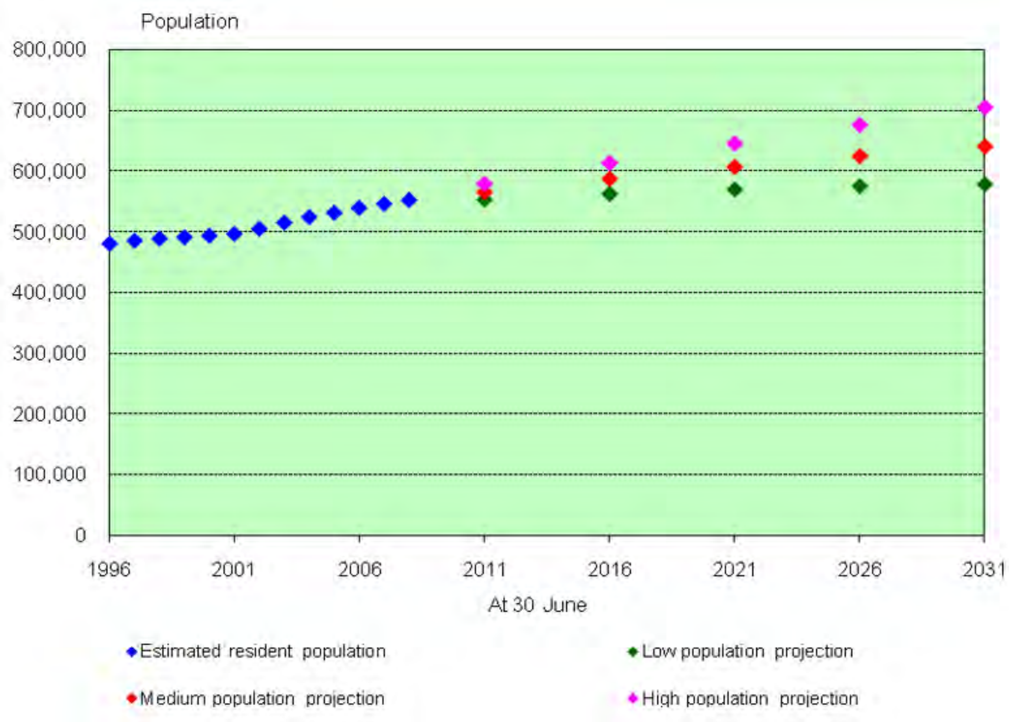


*Figure 1.5: Estimated and Projected Population – Canterbury Region*

## Proportions of the population aged 65 years and over

Fewer people per household are projected in all territorial authorities and regions, largely due to the general ageing of the population. More people are moving into older ages where they are most likely to live as couples without children or one-person households.

As a result, some areas with a projected decrease in population may have a projected increase in households

This reinforces the importance of the population projections in providing information about the changing age structure, which is at least as important as changes in total numbers. The

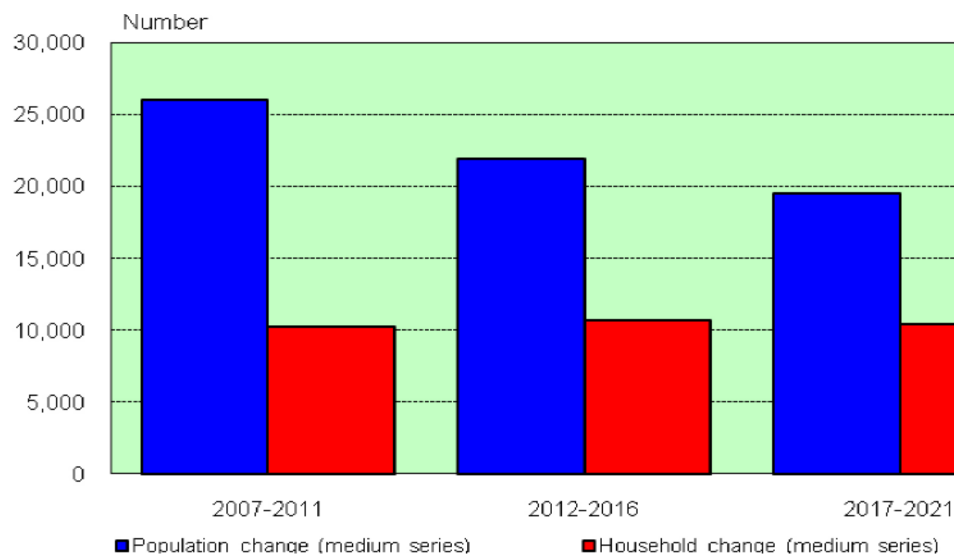


*Figure 1.6: Projected Population and Household Change – Canterbury Region (Source: Statistics NZ)*

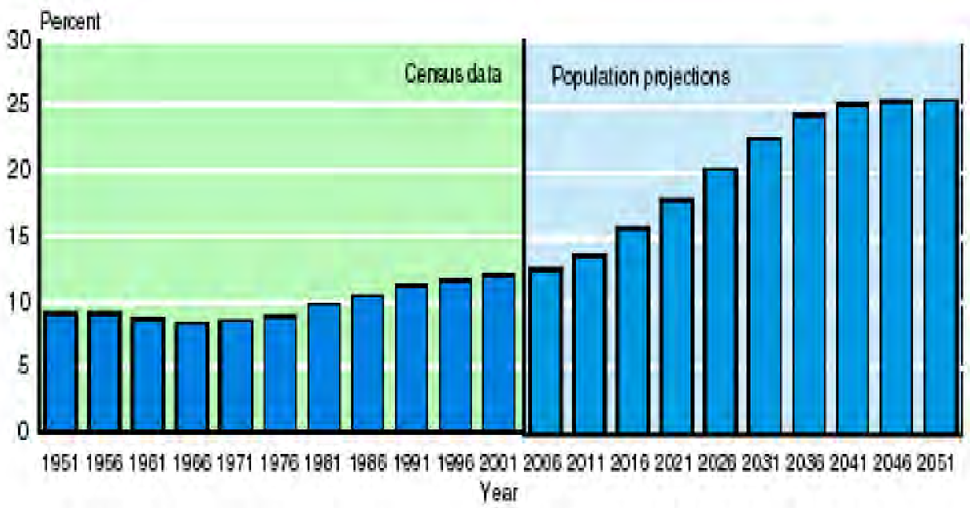


*Figure 1.7: Proportions of the population aged 65 years and over (Source: Statistics NZ)*

increase in the proportion of the New Zealand population aged 65 years and over the period 1951 to 2051 is indicated in Figure 1.7.

For each of the 10 councils in the Canterbury region, the proportions of population in each of the three age groups 0-14, 15-64 and 65+ are shown in Table 1.2 for the year 2006.

Overall, the growth of population, combined with aging demographics (which impact on things like public transport) are likely to put additional demand on existing energy supplies and infrastructure over the coming decades.

## 1.4 Economic Profile

The Canterbury economy accounted for 14.6% of total economic activity in New Zealand in the year to March 2004. Its regional GDP in the same year totalled $19.9 billion, with a per capita nominal GDP of $35,650 in the year to March 2003, compared to a national figure of $32,100. Canterbury's per capita real GDP grew at an average of 3.7% between March 1998 and 2003, well above the New Zealand growth rate of 2.3%. Canterbury's unemployment rate averaged 4.1% over the year to June 2004, compared to a national rate of 4.3%. The region's labour force participation rate is the highest in New Zealand, suggesting that the vast majority of able and willing workers are actively employed. This is reflected in the relatively high GDP per capita in the region. It also indicates that any additional economic growth will have to stem from population growth or labour and capital productivity gains. Labour productivity (real GDP per employee) in Canterbury grew at an average of 0.8% between 2000 and 2004. Nationwide, labour productivity growth averaged 0.9% per year over this period. Canterbury spends an above-average amount on economic development relative to its GDP ($1,300 per $million of GDP), compared with New Zealand as a whole ($1,100 per $million of GDP). Despite this expenditure, the region's enterprise creation and destruction rates are not vastly different from the national averages.

### 1.4.1 Economic Growth Prospects

Canterbury's economic growth between March 2000 and 2004 averaged 4.8%, compared to a national average of 3.5% for the same period, making Canterbury the second fastest growing region of those covered by NZIER's regional economic dataset. The steady growth in the Canterbury economy of the past few years is, however, expected to slow in the near term. Current forecasts indicate that the South Island economy is cooling, with the annual rate of economic growth forecast to fall from 3.8% to 3.2%. Although this cooling trend is expected to continue for a few years, economic growth is still predicted, but at a slower rate than the past few years. In the Canterbury region, there has most recently been a decline in economic growth, with growth of 2.2% (quarter for quarter) in quarter 1 of this year, giving way to a 0.4% drop in quarter 2. This has been primarily attributed to the Canterbury economy's exposure to manufacturing and tourism, which are particularly vulnerable to recent high exchange rates and increased oil costs.

### 1.4.2 Industry Profile

Figure 1.8 compares Canterbury's regional economic structure against the broader New Zealand economy. Plots to the right side of the dotted line (e.g. trade and tourism) indicate that the specified industry accounts for a greater proportion of the Canterbury GDP than it does at a national level; i.e. the industry is more 'important' to the Canterbury region than to the New Zealand economy as a whole. The figure above suggests:

- A high reliance on various manufacturing sectors, relative to the national economy
- A relatively high dependence on faster growing sectors (e.g. food, beverage, trade, tourism and other services)
- An under representation, relative to the New Zealand economy, in the business services, agriculture, natural resources and government sectors, which apart from business services, are all relatively slow growing sectors at the national level.

Fast-growing regions tend to have a high proportion of their regional economies focused on fast-growing sectors, which may explain in part why the Canterbury economy has grown rapidly in recent years.

## 1.5 Outline of Regional Energy Situation

Of current energy supply, the Canterbury region can at best be described as selectively endowed. The region produces around 28% of New Zealand's electricity supply from Meridian Energy's stations in the Waitaki system. Around 50% of the (net) production is consumed within the region with the remaining 50% being exported. However, the bigger picture also indicates that Canterbury, and the South Island in general, is becoming increasingly reliant on electricity deliveries from North Island thermal generation. In 2006, for the first time, the NZ Minzone was centred in the Upper South Island and not the Lower North Island. This southward shift simply reflects the dry year risk to South Island generation. The region does not have any hydrocarbon production aside from a small coalmine. All liquid fuels, gas and coal consumption, together comprising around 75% of total energy consumption, are imported, either from other regions within New Zealand or (originally) from

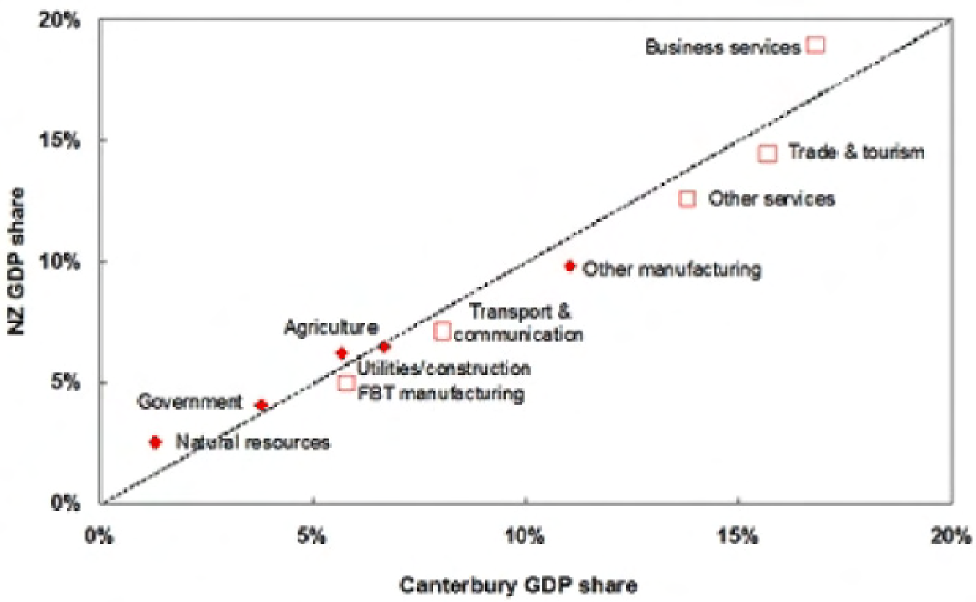


*Figure 1.8: Canterbury's Industrial Profile (Source: NZ's Regional Economic Performance - Regional Highlights 2006). Key: The square scatter plots are industries that are fast-growing at a national level. The black diamond scatter plots are industries that are slow-growing at a national level.*

overseas. A fuller description of energy supply, especially non-grid supply, into Canterbury, forms part of the ensuing discussion.

Environment Canterbury already conducts a biennial regional energy survey, the most recent of which was up to 2006 and published in 2008. This review used the data from the recent Canterbury Regional Energy Survey[1]. This report shows energy consumption trends from 1982 to 2006, updated at two-yearly intervals. The following is an excerpt from the Report's Executive Summary.

The focus of the survey and of the report was on the consumption of energy. A supply-side description and perspective of energy in Canterbury can be found in "CRESP: A Preliminary Stage 1 Report on Energy Security Aspects in Canterbury".

## Key Findings

**Total energy use plateaus**

Total energy consumption in Canterbury showed a slight decline (an average decrease of 0.1 % per annum) over the survey period (2004 to 2006). This is in contrast to the long-term trend for energy consumption, which since 1982 has risen at an average rate of 2.6 % per annum (See Figure 1.9). And in contrast to the national trend which showed an increase in total consumer energy for oil from 2005 to 2006 of 1.2%

This observed decline was the result of a reduction in the consumption of oil products in the Canterbury region. Oil products contributed 62 % of total energy consumption and for the survey period declined at an average rate of 1.2 % per annum.

The decline in energy consumption despite an increasing population in the region means that the energy consumption per capita also declined during the survey period.

**Domestic energy use is the fastest growing category**

While energy consumption in the transport sector and the industrial/commercial sector remained stable or declined over the survey period, domestic energy consumption increased by 2.2 % per annum (this is higher than the long-term average of 1.2 % per annum). Also in comparison, domestic energy consumption of electricity has been stable for the past 30 years per household nationally. The slow-down in energy consumption by both the transport and industrial/commercial sectors is due to a reduction in the consumption of oil products; this may be partly in response to recent increases in oil prices.

**Diesel is now the main type of vehicle transport fuel**

2005 was the first time that the survey recorded vehicle diesel consumption at a higher level than vehicle petrol consumption. In the Canterbury region the two major consumers of diesel are agriculture and freight; the increase in diesel consumption suggests that either or both of these sectors have experienced reasonable growth over the last few years.

**$CO_2$ emissions decreasing**

A decline in the consumption of oil products has resulted in an equivalent decline in $CO_2$ emissions. During the survey period emissions in the Canterbury region were calculated to have decreased by 1.1 % per annum. In 2006 transport was the major emission source in the region, responsible for 82 % of oil products and coal related emissions; 69 % was from the Canterbury vehicle fleet, with the balance from air transport and marine transport.

It is important to note that emissions were only calculated for coal and oil products. The analysis does not take into account carbon emissions from other sources such as non-renewable electricity (which are assumed to be minimal), nor from non-energy sources such as deforestation and agriculture.

**Conclusion**

The results presented in all regional energy surveys prior to this one illustrated an overall trend of increasing regional energy use and a dependence on imported oil products. The results in this survey depart from this trend; they show a noticeable decline in the use of oil products in the region for 2006. At present it is uncertain whether this decline could be representative of a stabilisation in energy use,

[1] Canterbury Regional Energy Survey 1982 – 2006, ECAN Report No. R08/14, ISBN 978-1-86937-776-2

in response to increasing cost and uncertainty over oil supplies, or a short-term effect.

In contrast the consumption of electricity in the region over the survey period continued to grow at a rate similar to the long-term average.

## Selected Survey Data

The majority of energy consumed in Canterbury comes from fossil fuels, contributing 68% of total energy. The relative contribution of fossil and non-fossil fuels has remained relatively constant throughout the survey's history.

The Canterbury region's energy consumption patterns and levels are broadly similar to national patterns and levels, with some difference noted below. A higher level of electricity consumption per capita substantially compensates for the non-availability of reticulated natural gas in the South Island.

Total energy consumption in the Canterbury region remained relatively stable, declining over the 2004-2006 period by 0.1 % per annum. This decline was due a decline in oil consumption over the survey period of 1.2 % per annum. In contrast, electricity consumption increased at 2.4 % per annum.

Oil products accounted for 62 % of energy consumption in 2006.

Canterbury's sectoral consumption patterns are slightly different from the national level. These differences are consistent with expectations. Cantabrians consume, hence spend, much more on transport energy than the national average. The industrial/commercial energy share per capita in Canterbury is lower than nationally and there is slightly higher domestic consumption per capita .

Over the survey period ( 2005 to 2006) energy consumption in the transport sector remained constant. Energy consumption by the industrial/commercial sector was observed to decline by 1.7 % per annum while domestic energy consumption increased by 2.2 % per annum.

In 2006 the energy consumption of road transport, aviation and marine were all observed to decrease. However, over the two-year survey period only marine energy consumption actually decreased, at a rate of 14.9 % per annum. For vehicle and aviation energy consumption the decrease in 2006 was not large enough to offset the increase in use in 2005. Although these changes appear, and may well be, significant, volatility of the marine energy series of this extent has been observed since the beginning of the series in 1982. Energy consumption for rail increased over the survey period at a rate of 17.9 % per annum.

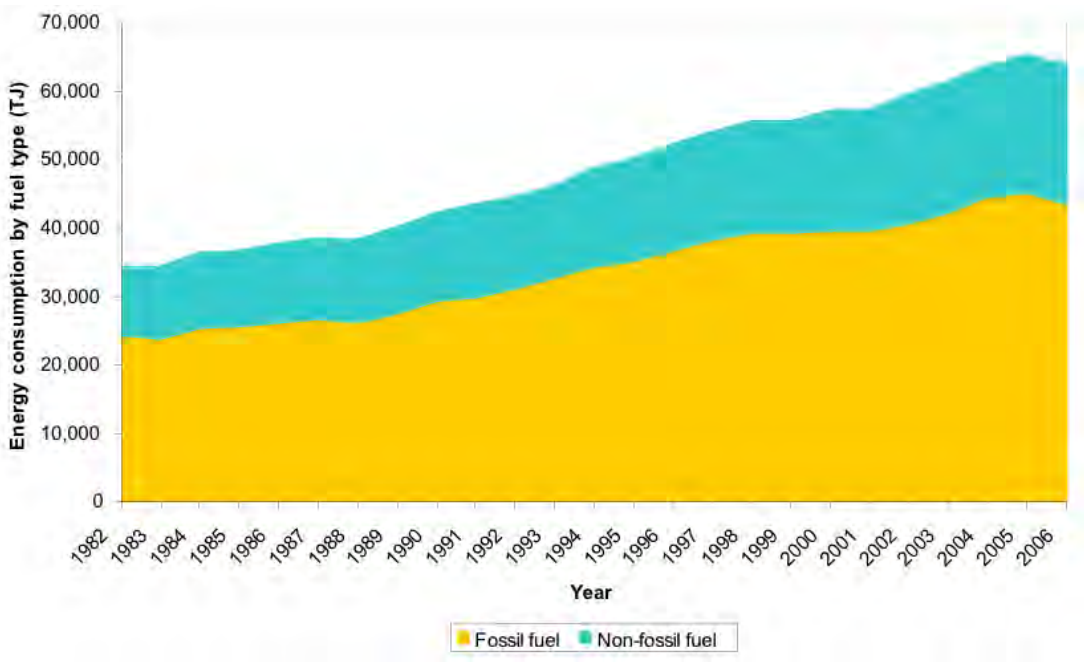


*Figure 1.9: Canterbury energy consumption by fuel origin*

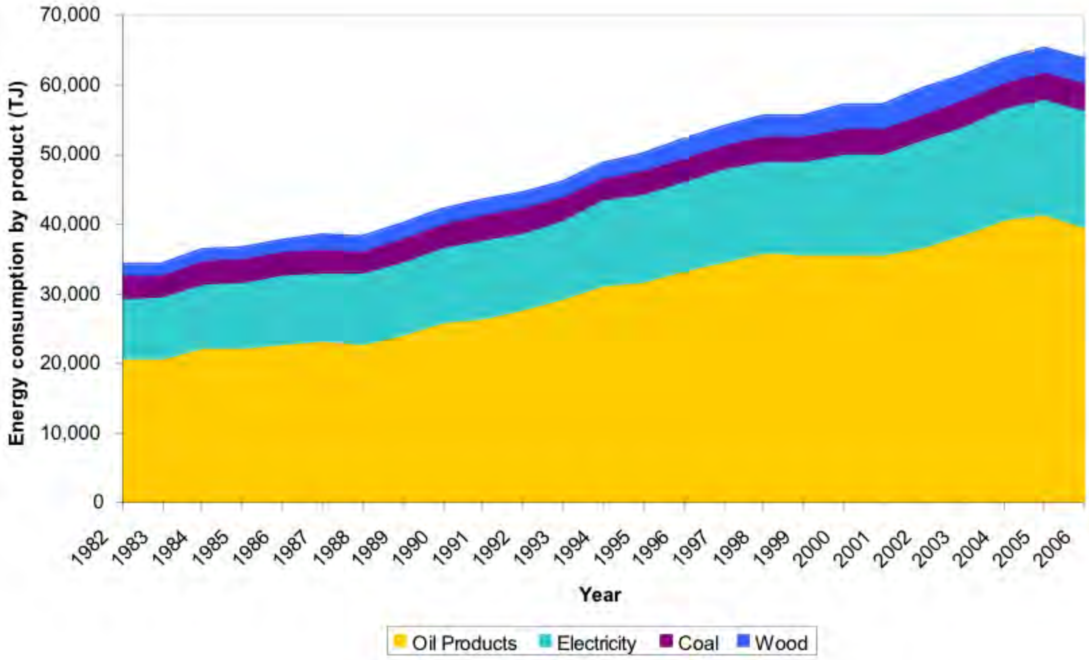


*Figure 1.10: Canterbury energy consumption by product*

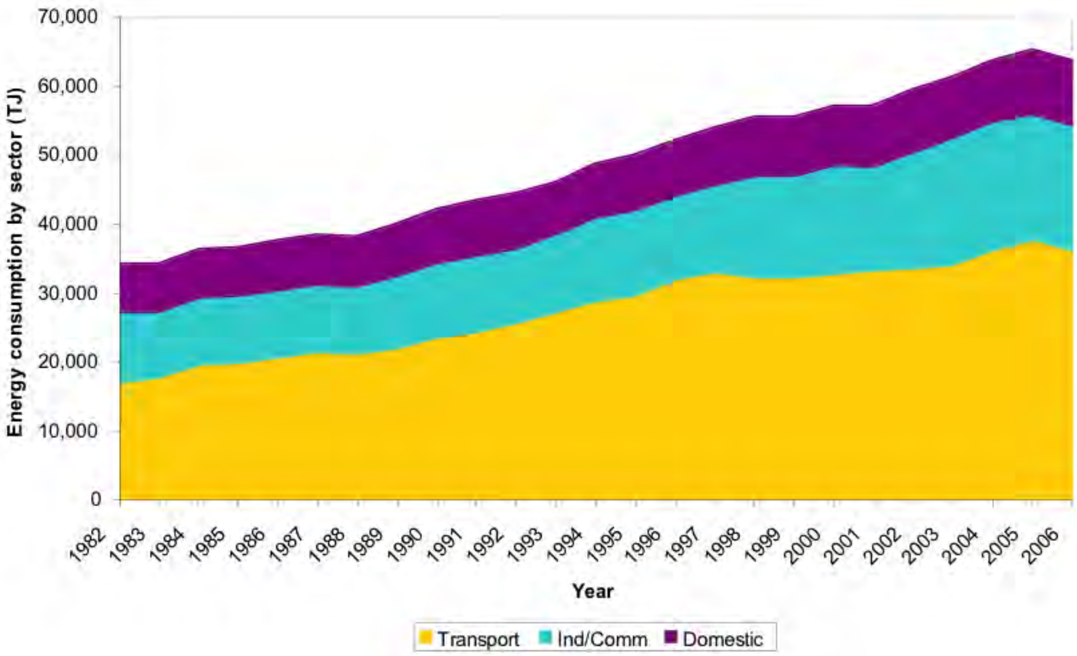


*Figure 1.11: Canterbury energy consumption by sector*

Road transport was the major consumer of total transport energy accounting for 70 % in 2006.

Petrol consumption was observed to decline annually by 1.6 % over the survey period. In contrast, vehicle diesel consumption increased, with an average annual increase of 3.9 % across 2005 and 2006, comprising an 8 % increase in 2005 and a small decline in 2006.

2005 was the first time that the survey recorded vehicle diesel consumption at a higher level than vehicle petrol consumption.

Energy consumption for each energy commodity has been divided into industrial/commercial and residential use. As this split was based on assumptions that are now dated the resulting information may not accurately reflect the current situation. However the data is useful

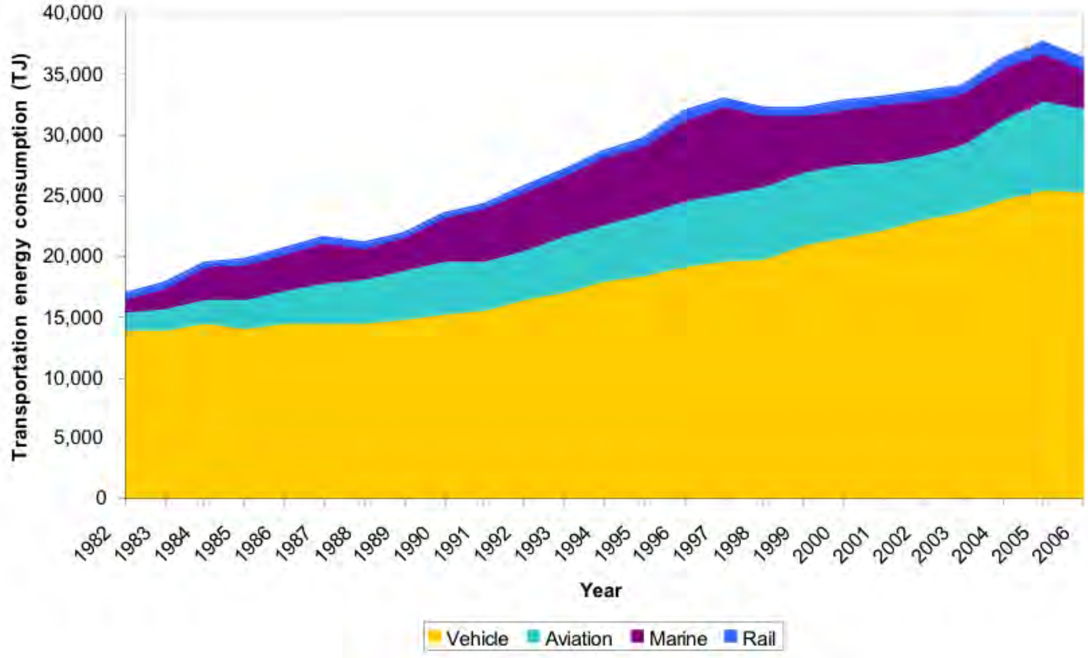


*Figure 1.12: Canterbury transportation energy consumption*

for identifying trends in the relative importance of each energy commodity for each sector. The data indicates that electricity is the dominant type of energy consumed in both the industrial/commercial and residential sectors.

A decline in GJ per capita was observed in 2006 for both energy consumption per capita and land transport energy consumption per capita. In both cases GJ per capita peaked in 2005. This observed slow down is due to a plateau in energy consumption across the Canterbury region despite an increasing population (see Figures 1.16 and 1.17).

$CO_2$ emissions declined over the survey period by 1.1 % per annum. As coal consumption was assumed not to have changed over the survey

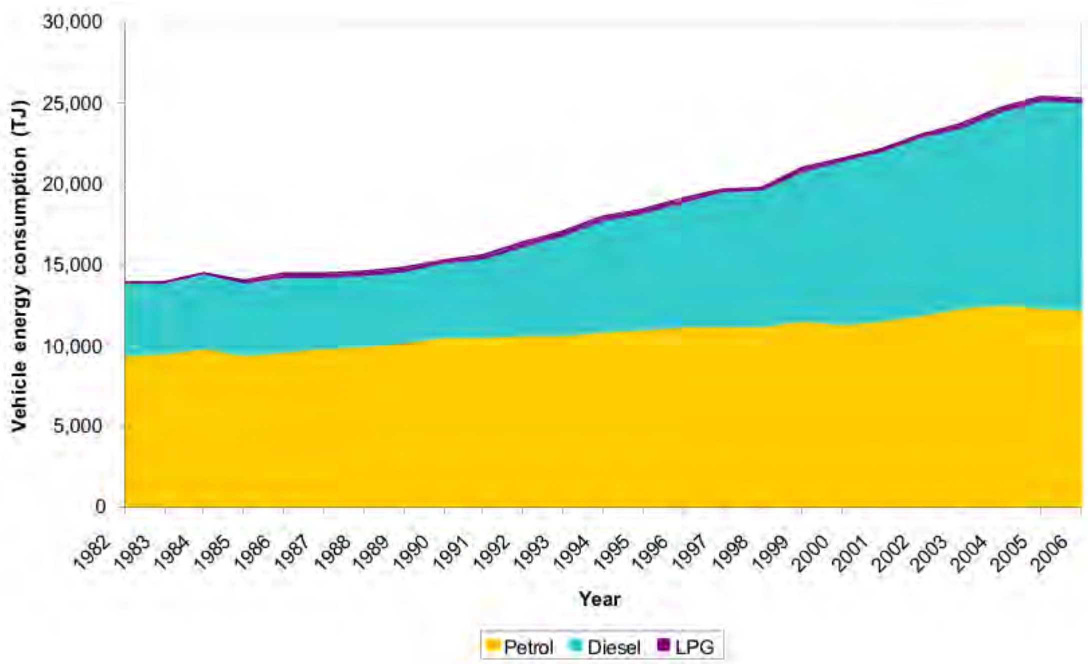


*Figure 1.13: Canterbury vehicle energy consumption by product*

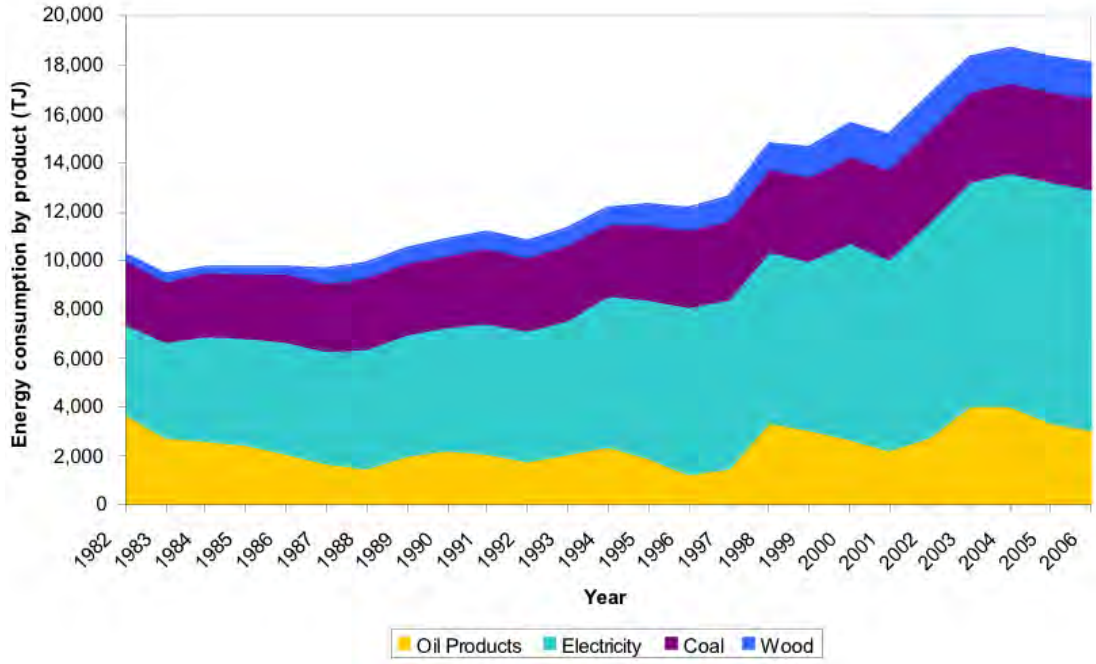


*Figure 1.14: Canterbury industrial/commercial energy consumption by product*

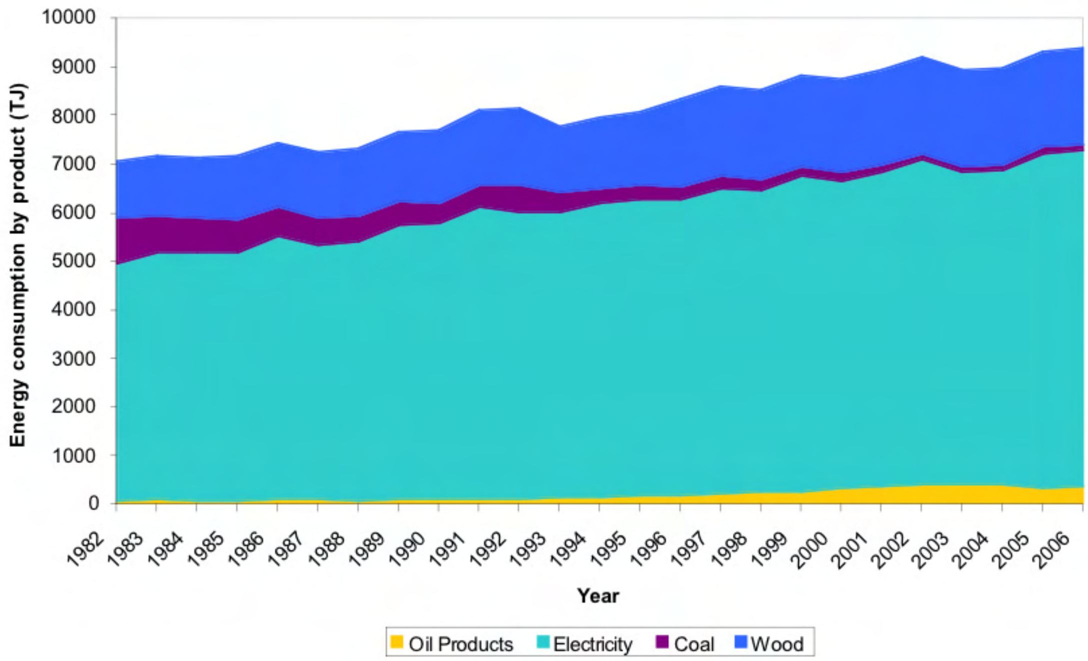


*Figure 1.15: Canterbury residential energy consumption by product*

period, and as wood and electricity are considered not to emit greenhouse gases, $CO_2$ emissions were observed to track oil product consumption[2]. It was calculated that in 2006 $CO_2$ emissions totalled 3.25 million tonnes. This represents as increase of 48 % over the international benchmark figure for 1990 (see Figure 1.18).

In 2006 transport contributed 82 % of $CO_2$ emissions from oil products in the Canterbury region. Furthermore, 69 % of the transport emissions were produced from the Canterbury vehicle fleet (aviation was the second largest contributor).

2 In the estimation of CO2 emissions it is assumed that all carbon in fuel in converted into CO2. Also CO2 equivalent effects of other greenhouse gases have not been taken into account.

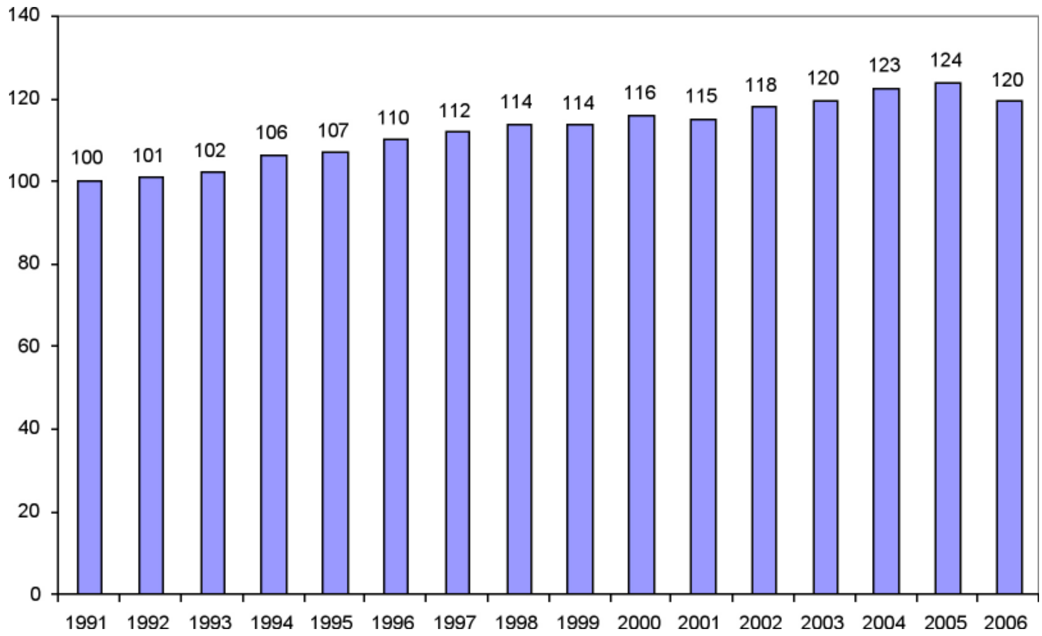


*Figure 1.16: Canterbury energy consumption GJ per capita*

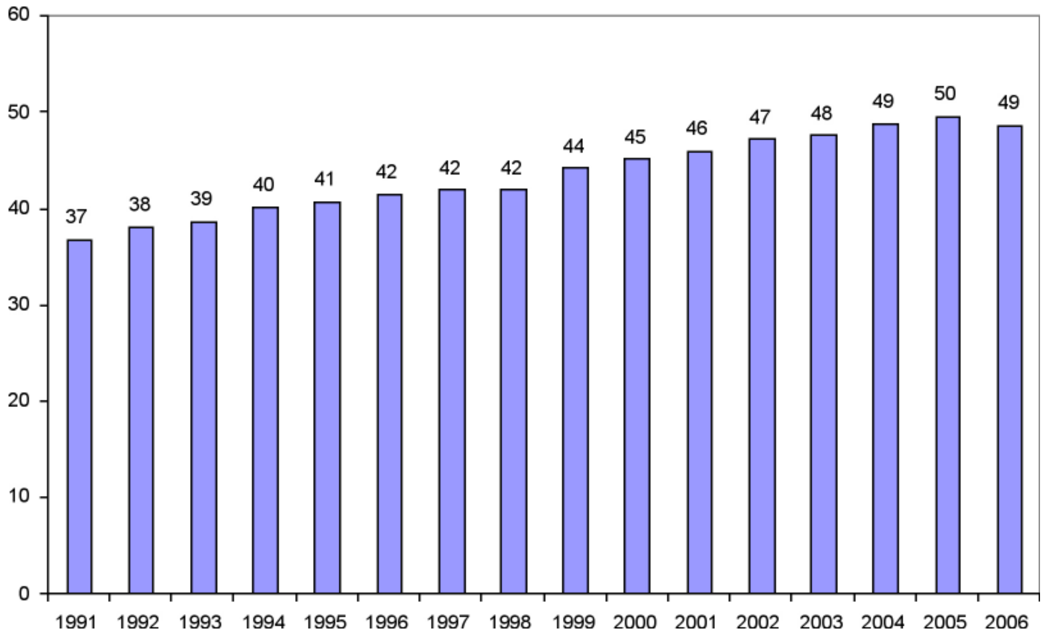


*Figure 1.17: Canterbury land transport energy consumption GJ per capita*

## 1.6 Climate Change and Energy

The Canterbury Regional Council prepared a report in February 2007: *Canterbury, its people, its resources -Climate Change - An analysis of the policy considerations for climate change for the Review of the Canterbury Regional Policy Statement.* For details see http://ecan.govt.nz/NR/rdonlyres/D4783BDC-B6C7-4299-8FD3-B264D4868508/0/ClimateChangeReport.pdf.

The effects of climate change are expected to become more pronounced. Canterbury is predicted to experience more droughts as the 21st century progresses (O'Donnell, 2007). There are energy implications for the Canterbury region, such as the management of summer peak electricity demand for energy-intensive irrigation (See Figure 1.19).

There are many other issues for energy, related to projected climate change in the period to 2030 and beyond. Rainfall is identified here as an example. Amongst other issues, rainfall is critical to hydro electricity production, and

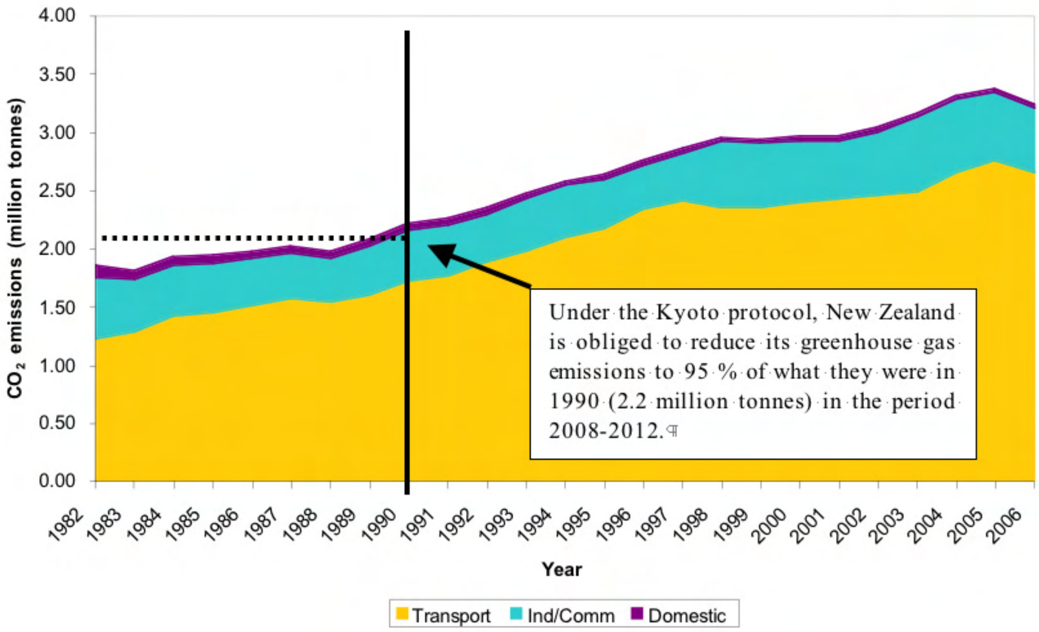


*Figure 1.18: Canterbury $CO_2$ emissions per sector*

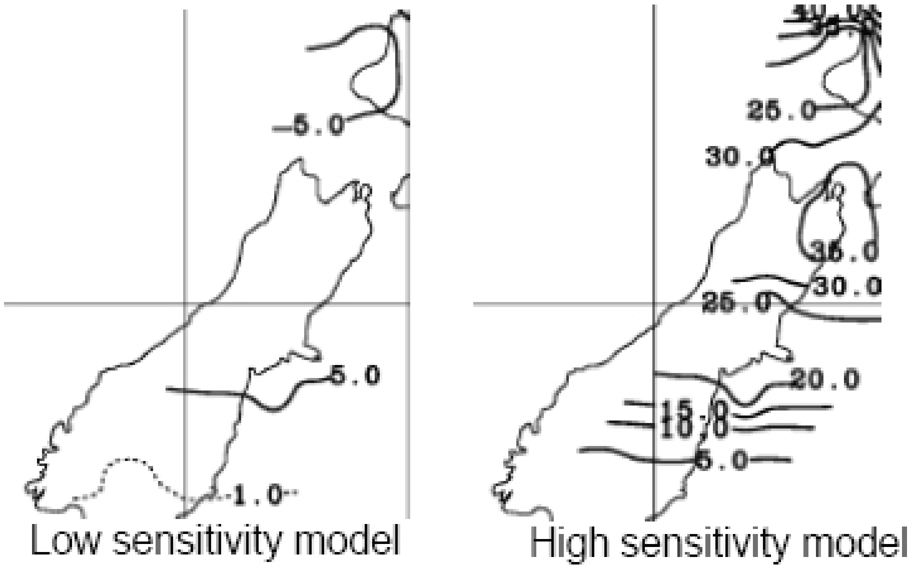


*Figure 1.19: Projected increase in the number of hot days (>25˚C) to 2100 Mullan, et al, cited in O'Donnell, 2007)*

irrigation energy issues.

**Mean Rainfall**

The picture for projected changes in regional rainfall is considerably more complex than that of temperature. Some major eastern rivers whose catchments reach back into the Main Divide could maintain or even increase flows, because of projected rainfall increases in these areas. These rivers are the Waitaki, Rangitata, Rakaia, Waimakariri and Hurunui. Although the Waiau and Clarence rivers are mountain-fed, significant increases in precipitation in the northern part of the region are not projected. However, it is noted that a change in phase of the Interdecadal Pacific Oscillation relative to 1978-1998 may mean that these precipitation increases do not eventuate over the next 20 to 30 years.

Overall, projections indicate that the Canterbury region will experience increasing rainfall in the ranges, and less rainfall on the plains. This has particular significance for groundwater recharge and foothills-fed rivers such as the Waipara, Ashley, Selwyn, Opuha, Opihi, Orari, Pareora, Waihao and Hakataramea, amongst others.

Although the increase in temperatures would be likely to induce a decrease in snow cover, warmer air holds more moisture, and during winter this could be precipitated as snow at high elevations. Therefore, warming does not rule out increased winter snowfall, although the duration of seasonal snow could be shortened and snowlines would rise.

Eastern parts of the region are projected to have less annual rainfall overall, particularly in the winter months. Mountain ranges in the north of the region are also projected to have less annual rainfall overall. However, significant increases in precipitation are projected for the Southern Alps, particularly in the winter. North Canterbury is of particular concern, as it is projected to suffer reduced precipitation throughout the year, which is coupled with a lack of alpine-fed rivers in the vicinity to provide more reliable water availability.

As winter rainfall is the largest contributor to groundwater recharge, climate change is likely to induce lower overall recharge and lower groundwater levels (see Figure 1.20).

## 1.7 Barriers to Renewable Energy

There are a range of barriers that have slowed the uptake of renewable energy. These largely relate to the need for individual projects to secure their own "fuel" supply from natural resources while also still having to construct an energy conversion facility (*i.e.* power plant). The locations where these natural resources are found often have other intrinsic value (such as wind resources found in areas of high landscape value, or hydro opportunities in dramatic catchment areas) or the resource itself has other competing uses (such as recreational

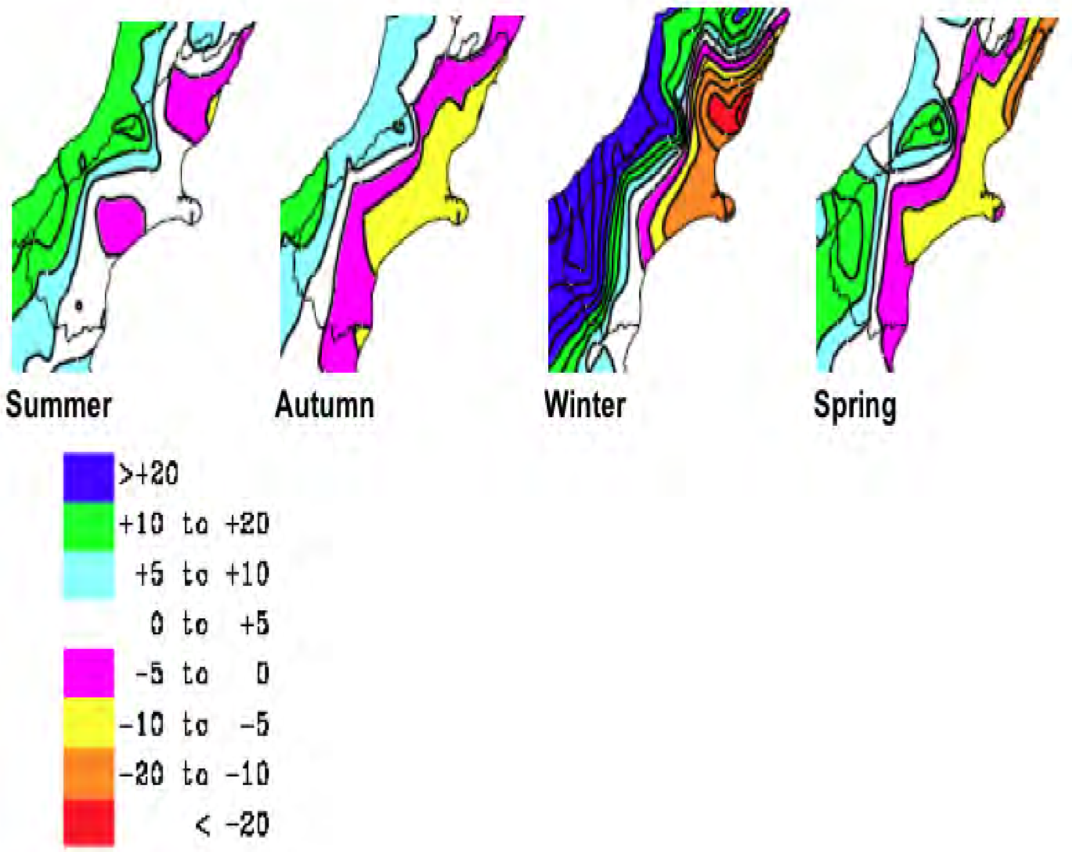


*Figure 1.20: Projected seasonal precipitation change (in %) for the 2030s relative to 1990: mid IPCC 2001 range (Source: Ministry for the Environment sourcing NIWA projections, 2004)*

use of rivers, geothermal features as tourist attractions).

For Canterbury, there are significant such areas that can be identified by elevation, natuve forest and Department of Conservation land. These are shown in Figure 1.21. For a larger scale of these maps, see Appendix C.

Some of the major barriers to renewable energy are identified in Table 1.3, along with a brief indication of where councils may have some influence on those barriers:

Fossil-fuelled projects face few of these obstacles. For example two gas-fired power plants under construction in 2006 did not require notified consents. The 1,000 MW Huntly plant has been reverted to being fuelled by coal so that the gas it would have otherwise used can be redirected to a new efficient CCGT gas-fired plant under construction. However, the conversion of the Marsden B plant to coal is subject to appeal on conditions by the developer and on environmental grounds by environmental groups opposed to the project.

Recent successful renewable energy projects have included an expansion to the Tararua wind farm and an expansion to the Mokai geothermal plant. These projects were located at existing power development sites and as such were readily able to obtain resource consents.

However, "green-field" projects tend to face greater difficulty within the RMA processes. The proposed expansions of the geothermal projects at Ngawha and Kawerau have been declined or face appeals because of perceived effects. Developments planned at new locations have had to follow a more difficult path. The hydro project "Aqua" was reportedly abandoned due to a perception of major public opposition, and several wind farms have faced similar opposition.

Developers report that small renewable

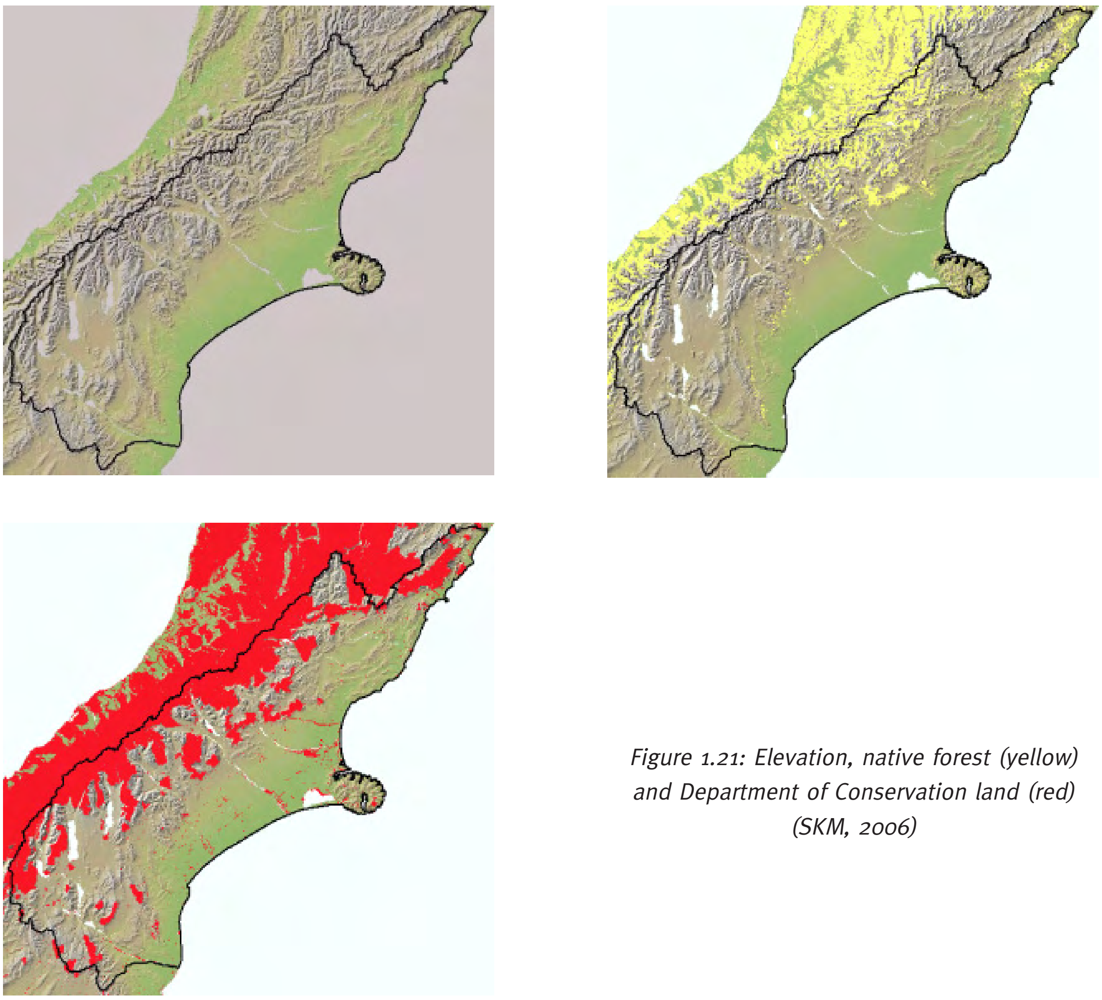

*Figure 1.21: Elevation, native forest (yellow) and Department of Conservation land (red) (SKM, 2006)*

projects are no longer viable to consider for development as the costs and delays associated with the consenting processes and the "mitigation" fees can be as great as for large projects. However, if fossil fuel costs and wholesale electricity prices continue to increase in line with recent trends then the higher market return possible for alternative energy sources will tend to enable the development of more renewable energy projects.

## 1.8 Canterbury generation update – January 2009

Table 1.4 shows five Canterbury generation projects which are currently under construction, have received consent or have applied for consent – sorted by earliest date. The Electricity Commission prepared their SOO document using information available in the public domain and in-house knowledge; it does not

| Barrier | Description | Council Influence |
|---|---|---|
| High capital cost | Projects include the cost of "fuel" gathering as well as energy conversion and hence tend to have high capital cost.<br>Some technologies are new and do not yet have the economies of scale in plant construction compared to conventional energy sources. | No influence |
| Intensive "fuel" investigation | Intensive investigation is required for determining resource potential. This is very high for geothermal but less for wind and hydro. | Consents for wind measurement towers, geothermal drilling and river weirs |
| Low energy density | Many renewable projects have a low energy density – requiring large areas for the collection of fuel and for energy conversion plant. However, some types such as wind and geothermal do not preclude continuation of other uses such as farming. | Land use that is allowed within human and natural land zonings. |
| Long development time | Most have several stages of development, from resource evaluation, consenting and construction. There are associated development risks at each stage. | Consenting process |
| Wide consultation<br>Community attitude to natural resource uses | The use of natural resources and construction of plant in natural areas demands a high level of consultation often in the face of significant public opposition. | Planning environment<br>Consenting process |
| Resources associated with natural features or areas of intrinsic or cultural value | Renewable energy can be associated with natural features that have high intrinsic value, such as wind in outstanding landscapes and hydro in natural waterways. These areas may also have special cultural value to Maori. | Landscape planning, natural area identification.<br>Balancing effects of development against amenity values in consent process. |
| Competing uses for the same resource | Recreation use of rivers and irrigation competes with hydro power. Geothermal surface features have a range of uses. | Balancing effects and benefits from competing uses<br>Resource consents to take water |
| High "mitigation" fees | Due the fact that objectors can impede the consenting process, many affected or interested parties now expect substantial fees in return for their agreement to a development. Consent requirements have resulted in a secondary mitigation fee market that is a barrier particularly for smaller projects. | Planning environment<br>Consenting process |
| Non-firm nature | Some renewable resources such as solar, wind and marine are periodic or intermittent in nature. This limits their ability to meet peak demand requirements and hence tend not to secure highest market prices. | No influence |
| Transmission requirements | Most renewable energy projects need to be located close to the energy resource and so are dependent on transmission networks to carry the energy to where it is required.<br>Weak transmission networks limit positioning of projects.<br>Developers may be required to build new transmission lines to service their projects. | Consents and designations for transmission upgrades or new lines |
| Environmental considerations | Councils may find it difficult integrating increased interest in renewable energy alternatives with local environmental concerns, already identified in existing or operative legislation.<br>For example the use of biomass as an alternative to electricity could be viewed as an air quality problem, rather than an energy supply solution. | Planning environment<br>Consenting process<br>Non-regulatory |

*Table 1.3: Major barriers to renewable energy projects (SKM 2006)*

use any material supplied by generators under confidentiality. It is subject to uncertainty and will change as more data comes to light.

Generation projects with capacity less than 5 MW are not shown. The data presented in italic are speculation.

| Resource | Location / Name of Project | Owned by | Capacity (MW) | Earliest commission date | Status |
|---|---|---|---|---|---|
| **Diesel** | Bromley | Orion | 11.5 | 2012 | Consented |
| **Diesel** | Belfast | Orion | 11.5 | 2012 | Consented |
| **Hydro** | North Bank Tunnel | Meridian Energy | 200-280 | *2015* | Applied for consent |
| **Hydro** | Rakaia River | Ashburton Com. Water Trust | 16 | *2015* | Applied for consent |
| **Wind** | Mt Cass | MainPower | 41-69 | *2015* | Applied for consent |
| | | **Total** | **280-388** | | |

*Table 1.4: Canterbury projects which are currently under construction, have received consent or have applied for consent – sorted by earliest date (Source: Electricity Commission)*

# 2 ENERGY RESOURCES POTENTIAL

The objective of this section is to identify mainly renewable energy resources but also other energy resources that are or may be found within the Canterbury Region and have potential for future development. Included is some background on resources outside Canterbury. There is a discussion on each resource particularly location, and the technology involved. However Section 3 describes each *technology for supply* (currently available or are being developed), with cost, risk and market potential. Most potential developments are likely to be more than 10 years away.

An initial assessment of the renewable energy development potential of the region was provided in the 2006 SKM report. The estimates of renewable energy potential sought to identify major resources that are available and to provide an indication of their relative magnitude. It is to be noted that the assessment did not account for how environmental and cultural issues would affect renewable energy potential. Rather, the assessment presented indicative estimates for the amount of renewable energy that could be realised in terms of the resource available outside National Parks and Department of Conservation lands (as a working, first order definition of what projects may be environmentally acceptable; refer to maps, section 1.7, Figure 1.21) using technologies that are already economic or are likely to become economic over the course of the next ten years (i.e. the review period of Regional Policy Statements). Information from the 2006 SKM report has been updated where possible.

[Sinclair Knight Merz (SKM) Renewable Energy Assessment – Canterbury Region, July 2006]

## 2.1 Water – hydro – small, medium, large

### 2.1.1 Previous Hydropower Capacity Studies

The potential for developing the hydro-electric potential of New Zealand has been the subject of study for more than 100 years, the milestone reports being:

1 **The Hay Report (1904):** The earliest full assessment of New Zealand's hydro-electric resource was conducted in 1904, when North and South Island reports were tabled in the House of Representatives. Nearly all of the schemes which have so far been developed were identified in these original reports.

2 **Ministry of Works and Development (1982):** MWD undertook a comprehensive assessment of the country's small and medium scale hydropower potential in the period 1978 to 1985, establishing a consistent assessment methodology to look for sites with a potential installed capacity in the range 500 kW to 50 MW assuming a typical plant factor of around 50%. The work involved a review of maps, gauged river flows and topography to identify opportunities for harnessing water power. Local features of the most promising sites were then assessed and preliminary concepts were devised. In the early 1980's, a series of assessments of most of the hydropower potential in the Canterbury region were made by various consultants. The assessment covered the North, Central, South Canterbury and Waitaki catchments separately.

   The potential schemes and their scheme parameters are tabulated by catchment area in Appendix B. The locations of the previously identified potentially attractive schemes in the region are shown on Map 1 (Appendix C).

3 **WORKS (1990):** Another nationwide survey was undertaken by WORKS which summarised the large schemes (>10 MW) from previous studies and went on to consider the practicability of some of the major schemes including some very large opportunities in South Island. This study concluded that the Canterbury region had a potential of 3,120 MW (including the 240 MW in the lower reaches of Clarence River).

4 **Ministry of Economic Development (2004):** In their 'Waters of National Importance' report, East Harbour Management Services considered the hydro-electric resources of New Zealand.

A 'publicly known' nationwide future hydropower potential of around 2,500 MW is considered, recognising also that there are possibly a significant number of opportunities not publicly identified. In the Canterbury region four catchments were considered in the 'high' and 'medium' confidence category having a combined capacity of 910 MW, equivalent to 36 % of the national future potential.

5 **EECA Renewable Energy Industry Status Report (2005):** On behalf of EECA, East Harbour Management Services went on to report on the nationwide potential for additional renewable power generation. On a national basis, the report estimated an additional annual hydro potential of some 4,260 GWh (equivalent around 900 MW with a typical plant factor of 50%). Cost estimates were based on escalating the MWD data from the 1980's. In the Canterbury region, the report found 13 potential schemes below 16 c/kWh at10% weighted average cost of capital (WACC) with an estimated installed capacity of 349 MW.

6 **Ministry of Economic Development (2005):** East Harbour Management Services reported on the overall scope and cost ranges for generating electricity and heat from renewables. In the Canterbury region 14 possible hydro schemes were identified with a total installed capacity of 349 MW.

7 **Electricity Commission (2005):** As part of the Electricity Commission's Statement of Opportunities a report was compiled by Parsons Brinckerhoff which provided a summary of all previously identified schemes – large and small. The report included cost estimates escalated from the MED report and developed ranges of possible cost (on a theoretical basis only) for schemes not previously estimated. The report summarised the schemes from previous references.

### 2.1.2 Background

Canterbury has 78,162 km of rivers and 4,753 lakes with a surface area of 702 km². For this hydro assessment, the Canterbury region has been divided into eight areas that combine several catchments within them. The major rivers and lakes in these zones are given in Table 2.1.

A map of the location of river catchments is shown in Figure 2.1.

### 2.1.3 Developed Hydropower Resources

The existing hydropower development in the Canterbury region is summarised in Table 2.2. The total storage in the Waitaki lakes is 2511 GWh and this is relatively small compared with

| | Catchment Areas | Major River(s) | Lakes | Region |
|---|---|---|---|---|
| 1. | Waiau, Clarence and Coastal Kaikoura | Waiau, Clarence | | North Canterbury |
| 2. | Hurunui | Hurunui | | |
| 3. | Waipara and Ashley | Waipara, Ashley | | |
| 4. | Waimakariri | Waimakariri | | Central Canterbury |
| 5. | Rakaia, Selwyn and Banks Peninsula | Rakaia, Selwyn | Lake Coleridge | |
| 6. | Rangitata and Ashburton | Rangitata, Ashburton | | South Canterbury |
| 7. | Opihi-Orari and Coastal South Canterbury | Orari, Opuha, Opihi, Tengawai, Pareora, Waihao | | |
| 8. | Waitaki | Waitaki | Pukaki, Tekapo, Ohau, Ruataniwha, Benmore, Aviemore, Waitaki | Waitaki |

*Table 2.1 Canterbury – Catchment Areas, Major Rivers and Lakes*

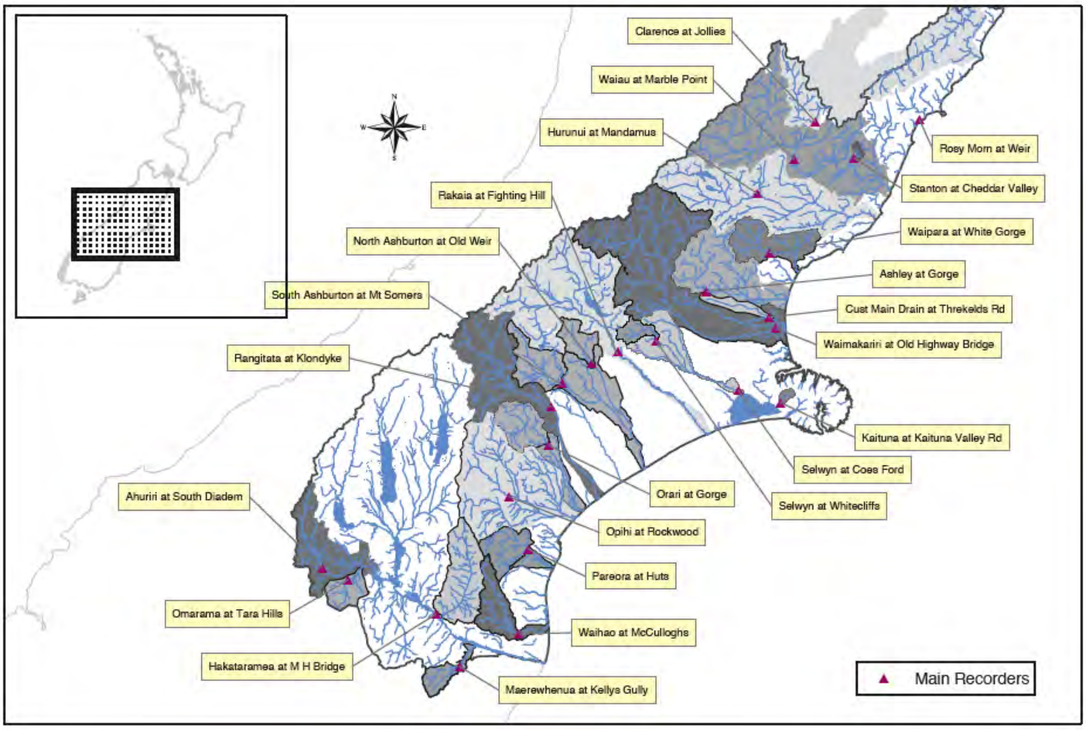


*Figure 2.1 Location of river catchments*

the average annual generation of 7702 GWh in the Waitaki. Small developments on irrigation canals are not included.

http://www.meridianenergy.co.nz/NR/rdonlyres/B496C006-3F64-4F0E-8305-C22CAE732A4E/24505/0104MEDWaitakiwebBr012.pdf.

### 2.1.4 Canterbury Hydro Generation Proposals and Opportunities

For possible future hydropower potential see Appendix B: Previously Identified Hydro Schemes in Canterbury. There are 65 schemes listed, with some overlaps, and many inter-dependencies and incompatibilities.

The following sections describe the hydro potentials in the different catchment areas.

#### 1 Waiau, Clarence and Coastal Kaikoura

The area covers the region drained by Waiau and the Clarence Rivers. The area extends from the east coast to the Southern Alps and is bounded by the Inland Kaikoura Range in the north. The Waiau River rises from the steep headwaters of the Southern Alps, passes through the rolling hills in the middle and lower reaches and drains into the Pacific Ocean after flowing over flat land of the Hanmer Plains.

A total potential of 430 MW was identified as being probable on the Waiau River and its tributary, the Hope River. A dam/powerhouse scheme on the Hope River (C10) may have a potential of around 55 MW. A series of five dam/powerhouse schemes and two power-house schemes with a canal diversion along the Waiau River (C11 to C18) have been described to have a potential of around 375 MW. Additional 180 MW is possible if the diversion from Clarence River and Hurunui River is considered. Three smaller schemes were identified on the river - two on its tributaries and one in conjunction with the Waiau Irrigation Scheme, with an estimated installed capacity of around 9 MW. On the lower reaches of the Clarence River around 210 MW was assessed to be potentially available from two schemes. Several schemes that divert water out of the Clarence River to the Waiau and Conway Rivers have been described in earlier assessments.

A scheme (C4) that extracts water from the Clarence River to the Waiau River, known as the *Clarence to Waiau Diversions* is a proposal

| Catchment Area | Scheme (a) | Scheme Rating (MW) | Average Annual Generation (GWh) | Owner/Operator |
|---|---|---|---|---|
| Rakaia | Coleridge (3)<br>Highbank (4) | 39<br>28 | 270<br>86 | TrustPower<br>TrustPower |
| Rangitata, Ashburton | Montalto (5) | 1.1 to 1.8 | 12 | TrustPower |
| Opihi-Orari and Coastal South Canterbury | Opuha | 7 | 4 | Operator-<br>Contact Energy |
| Waitaki | Aviemore (1)<br><br>Benmore (2)<br>Ohau A (6)<br>Ohau B(7)<br>Ohau C(8)<br>Tekapo A(9)<br>Tekapo B (10)<br>Waitaki (11) | 220<br><br>540<br>264<br>212<br>212<br>25<br>160<br>105 | 942<br><br>2215<br>1140<br>958<br>958<br>160<br>833<br>496 | Meridian Energy Limited (MEL)<br>MEL<br>MEL<br>MEL<br>MEL<br>MEL<br>MEL<br>MEL |
| | **Total** | **1,826** | **8074** | |

*Table 2.2 Canterbury – Developed Hydropower (a). Figures in brackets are 'Map 1 - Existing Hydro Schemes' Reference Number (Appendix C) (SKM 2006, updated and includes Opuha)*

for 70 MW of new hydro (run of river) generation connected at Culverden by 2018. http://www.gridnewzealand.co.nz/f41,2256/2256_canterbury-regional-plan.pdf

Another scheme (C5) that consists of a diversion from the Clarence River to a powerhouse on the Conway River and then on to another power station on the coast near Oaro would have a total combined potential of around 480 MW. These schemes are not compatible with each other and other schemes on the river. An indicative summary of potential hydro generation in the Waiau, Clarence and coastal Kaikoura catchments is shown in Table 2.3

**2 Hurunui**

The Hurunui River rises in the Southern Alps and flows into the Pacific Ocean travelling over around 150 km and has a catchment of approximately 2,671 km². The headwater area of the river contains numerous lakes and contains mountains that rise over 1,800 m. The catchment has three areas that exhibit distinctive characteristics – upper mountainous region, middle plains and lower rolling hill country. Two major strands of the Alpine Fault

| River / Scheme | Capacity (MW) | Remarks |
|---|---|---|
| Waiau & Hope Rivers (C10 to C18) | 430 | Total potential |
| Diversion from Clarence & Hurunui Rivers | 180 | Extra to above |
| Waiau, smaller schemes | 9 | Includes Waiau Irrigation |
| Clarence to Waiau diversions (C4) | 70 | Proposal for 2018 |
| Clarence, lower reaches (C5) | 210 | 35 MW in 2029? |
| **Rounded Total** | **900** | Or other combinations |

*Table 2.3 Waiau, Clarance and coastal Kiakoura catchments - summary of potential hydro generation*

cross the region – the Hope Fault and the Clarence Fault. The climate in the catchment is affected by the north-westerly wind flow, with the headwaters experiencing around 5000 mm of annual precipitation, decreasing to less than 1000 mm in the coastal region.

The Hurunui River has been assessed to have considerable potential for small hydro development. A total of around 180 MW may be possible from four different dam/powerhouse schemes on the river. The location of the first scheme is around 2 km downstream of the Seaward River while the second scheme is at around 1 km downstream of the Glenrae confluence. The third scheme is located where the Hurunui River breaks through the Lowry Peaks and the fourth scheme is around 24 km from the mouth of the river. Diversion of water to the Waiau River upstream of the third scheme would potentially make the lower two schemes uneconomic but would result in additional generation capacity from the schemes on the Waiau River.

*Hurunui Water Project*. MainPower has committed to support the development of economic growth and environmental improvement in the North Canterbury region. One of the company's projects is to assist the North Canterbury community to investigate the options for sustainable water usage and storage in the Hurunui River catchment. MainPower is a partner in the Hurunui Water Group. The role of the group is to consider options for water management. This includes potential for hydro electricity. The Project is centred on an area of around 42,000 hectares in the Hurunui and Upper Waipara catchments - see Figure 2.2.

The potentially irrigable land includes supplementing the existing Amuri Irrigation Company Ltd (AICL) Balmoral Scheme supplied via the Hurunui River, non irrigated areas adjacent to the Balmoral Scheme, the Hawarden area, Scargill Valley, North Waipara, Masons Valley and Omihi. Investigations since 2003 have led the Project to focus on twin storage sites at Lake Sumner and the South Branch of the Hurunui River - see Figure 2.3.

Current studies are focused on the hydrology of the water bodies. Public consultation is in

*Figure 2.2 Map showing irrigable area*


*Figure 2.3 Map showing storage sites*

progress (Feb 2009). http://www.hurunuiwater.co.nz/_documents/119/Hurunui%20District%20map.pdf

Other schemes that were identified in earlier assessments on the Hurunui River and its tributaries are as follows:

- Lake Sumner (C19): A run of river scheme with the intake at the lake outlet and a powerhouse around 4.5 km downstream would generate around 4.3 MW. The other alternative is a 10 m high dam located 2.5 km downstream of the outlet, which would have a potential of around 8 MW.
- Sisters Stream (C20): There may be potential for a 700 kW scheme that uses a waterfall just above its confluence with Hurunui River.

- Dam options on the North branch (C21): The first option described in the earlier reports consists of a dam at the Sisters Gorge impounding the water and flooding flat river terraces upstream that would have a potential of around 17.6 MW.
- Balmoral Irrigation (C22): Two possible sites along the proposed waterway of the Balmoral irrigation scheme may have a potential of 1 MW to 2 MW.

An indicative summary of potential hydro generation in the Hurunui catchments is shown in Table 2.4.

### 3 Waipara and Ashley

The Ashley River rises in the foothills of the Alps and flows east to the Pacific Ocean. The upper catchment is predominantly mountainous area while the lower region downstream of the foothills is flat plains. The annual rainfall over the catchment varies between 2,400 mm at the headwater region to around 700 mm in the coastal area. Two potential schemes (C27) were identified along the river – an option with a dam and a diversion tunnel with an estimated installed capacity of 7.7 MW or an approximately 5 MW run of the river scheme downstream of the Ashley gorge bridge.

The Waipara River has a catchment of around 740 km$^2$ with the headwaters in the foothills of the Southern Alps. The river was assessed as not having any hydropower potential, mainly due to its low flows as a result of the catchment being in the rain shadow.

An indicative summary of potential hydro generation in the Waipara and Ashley catchments is shown in Table 2.5.

### 4 Waimakariri

The Waimakariri rises in the Southern Alps near Arthurs Pass and flows eastwards to its mouth near Kaiapoi in Pegasus Bay, with the lower half flowing over the Canterbury plains. A total hydropower potential of 530 MW has been estimated along the river. Around 140 MW comes from two schemes (C31, C32) at the Waimakariri Gorge and another scheme (C33) 90 MW at the narrow section just upstream of the State Highway 72 bridge have been identified. A complex scheme that diverts Waimakariri River to Ashley River has been discussed in an earlier assessment and is estimated to have a capacity of around 250 MW but such a scheme would conflict with other schemes downstream. Another 300 MW is has been estimated to be possible in the lower reaches, however this has not been investigated to any details. A 35 MW scheme (C30)has been identified as possible on the Poulter River, a tributary of the Waimakariri River. The development in the river would benefit from the close proximity of the major load centre at Christchurch. However it is also recognised that the river's high recreational

| River / Scheme | Capacity (MW) | Remarks |
|---|---|---|
| Hurunui River | 180 | 4 schemes |
| Hurunui Water Scheme | ? | Irrigation, with hydro potential |
| Lake Sumner (C19) | 4.3 or 8 | The Hurunui Water project may exclude these |
| North Branch (C21) | 17.6 | |
| Balmoral Irrigation (C22) | 1 to 2 | |
| **Rounded Total** | **200** | |

*Table 2.4: Hurunui catchments - summary of potential hydro generation*

| River / Scheme | Capacity (MW) | Remarks |
|---|---|---|
| Ashley (C27) | 7.7 or 5 | |
| Waipara | 0 | No potential identified |
| **Rounded Total** | **10** | |

*Table 2.5: Waipara and Ashley catchments - summary of potential hydro generation*

value may constrain its development.

*Irrigation developments*

The Central Plains Water Trust (CPWT) has applied for a number of resource consents relating to the construction and operation of a large scale irrigation scheme. The applicants propose irrigating 60,000 hectares of land between the Rakaia and Waimakariri Rivers, an area stretching from the Malvern foothills to State Highway One. See Figure 2.4

The proposal includes a 55 metre high dam containing a 12 km $^2$ storage lake. Water would be distributed from the lake via a 10km tunnel and an extensive network of distribution canals directly to irrigators. Under the proposed scheme, water would be abstracted at a rate of up to 40 cumecs (cubic metres per second) from each of the rivers through two intakes on the Waimakariri River and one on the Rakaia. Central Plains Water Trust has been granted requiring authority status by the Minister for the Environment, enabling it to apply to local councils to 'designate' or set aside land that it needs to set up infrastructure.

In the Selwyn and Waimakariri area existing schemes now water 18,000 ha, but there is potential to irrigate a total of 141,000 ha using water from the Rakaia and Waimakiriri rivers. Two storage options in this district considered by Aqualinc were the Lees Valley and the Waianiwaniwa Valley. A dam in the Lees Valley would, at 180 m, be a very high dam, storing water from the Waimakariri river and releasing it into the Ashley River. Water from this dam could irrigate all of the potentially irrigatable area. Because of its height and size there would also be significant opportunity for hydroelectric generation and recreation facilities on this dam. The Waianiwaniwa option is similar to that proposed by Central Plains Water, in that storage would be filled by water from the Waimakariri via races. It would be smaller than the Lees Valley option and would irrigate about 45% of the potential area. The issues and challenges of the Lees Valley dam

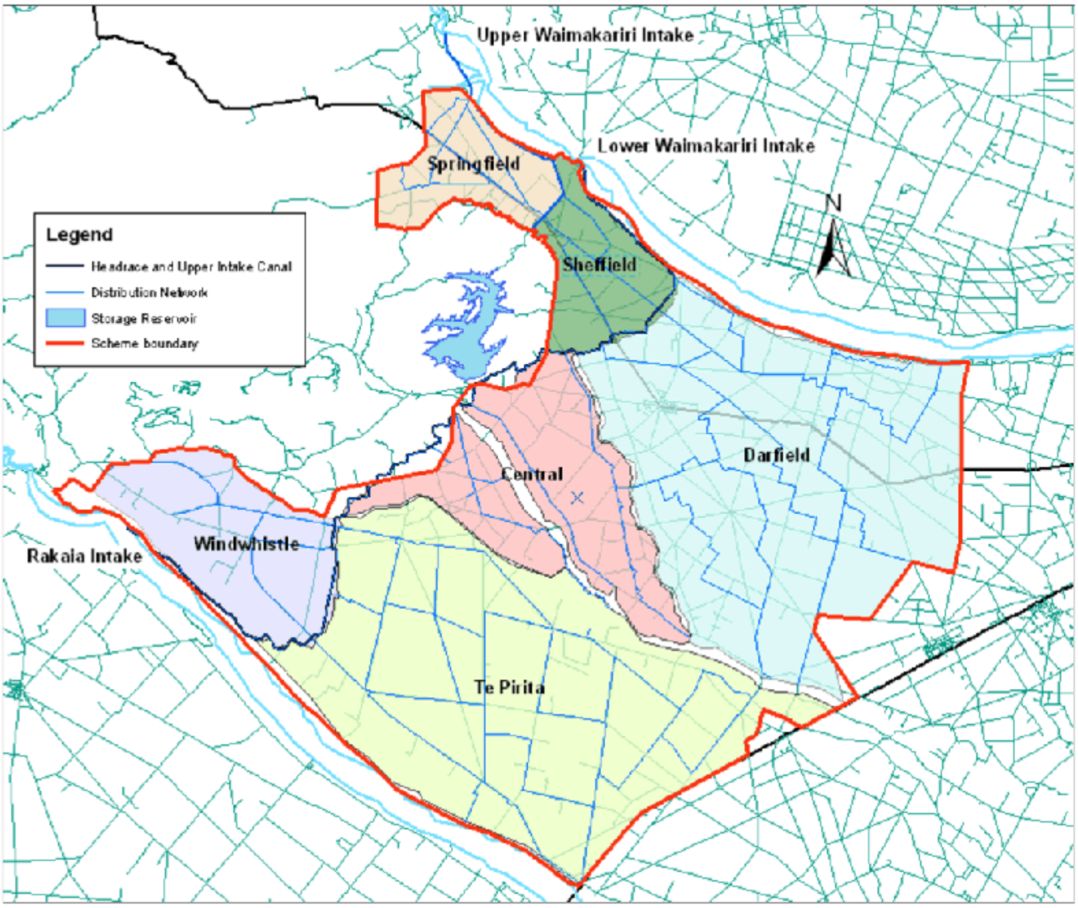


*Figure 2.4: Central Plains Water Trust Proposed Scheme*

include the fact it would take 10 years to fill and the sheer scale of the dam. Also flow regimes would impact on the normal variable flows in the Ashley River.

Water from storage and the distribution of the water down the slope of the plains (1 in 170) provides the opportunity for small scale generation. There is already potential for small scale generation at the drop structures on the existing irrigation canals and the raceways within the district. http://www.country-wide.co.nz/article/9153.html

An indicative summary of potential hydro generation in the Waimakarri catchments is shown in Table 2.6.

### 5 Rakaia, Selwyn and Banks Peninsula

The Rakaia rises in the Southern Alps with the headwaters in the Lyell and Ramsey Glaciers, crossing the Canterbury Plains to flow into the Canterbury Bight.

A total of approximately 570 MW has been estimated to be possible from two large hydropower schemes on the Rakaia River. These would include a 250 MW scheme (C38) at the Rakaia Gorge and 320 MW from a scheme with a canal and several power stations. However there are water conservation orders in place, and the high recreational use of the river (such as fishing) will constrain the development of hydropower schemes in the future. An extension and upgrading (C37) of the existing 39 MW station at Lake Coleridge is estimated to add potentially another 50 to 60 MW (see Figure 2.5).

The potential of Banks Peninsula is not known to have been assessed previously, though the relatively small catchments and the widely fluctuating rainfall patterns do not obviously lend themselves to run-of-river type mini hydro developments.

*Figure 2.5: Lake Coleridge Basin*

The Ashburton Community Water Trust (ACWT) and Ashburton District Council have been granted consents to use Rakaia River water to generate electricity (said to be some 22 MW maximum capacity), subject to the applicant undertaking a full summer ecological survey. (December 2008). This *Rakaia Terrace Hydro Scheme* proposes to take up to 40 cubic metres of water a second all year round at Highbank, for hydro generation, and discharge it back into the river at Barrhill. The interim decision notes that any water take and use consents for the hydro scheme will be separate from any considered for CPWT irrigation scheme and that this decision does not prejudice the CPWT hearing outcome. That decision is not anticipated until May 2009.

www.ecan.govt.nz/NR/rdonlyres/0C5FFA2F-715F-48A1-8E7D-93E563A592E5/0/interimdecisiononacwt_optimised.pdf

An indicative summary of potential hydro generation in the Rakaia, Selwyn and Banks Peninsula catchments is shown in Table 2.7.

### 6 Rangitata and Ashburton

Around 25 km from the main divide, the Clyde and the Havelock Rivers that rise in the Southern Alps combine to form the Rangitata River. The river passes through a broad gravel bed, passing through a gorge approximately 40

| River / Scheme | Capacity (MW) | Remarks |
|---|---|---|
| Waimakariri - total | 530 | 530 MW is unlikely |
| Poulter River (C30) | 35 | |
| Central Plains or similar | ? | |
| Canal drop structures | ? | Within existing and proposed schemes |
| **Rounded Total** | **570** | |

*Table 2.6: Waimakarri catchments - a summary of potential hydro generation*

| River / Scheme | Capacity (MW) | Remarks |
|---|---|---|
| Rakaia river | 570 | 570MW possible, but unlikely |
| Lake Coleridge | 50 to 60 | Extension & upgrading |
| Rakaia Terrace Hydro | 22 | Provisionally consented |
| Canal drop structures | ? | Within existing schemes |
| **Rounded Total** | **650** | |

*Table 2.7: Rakaia, Selwyn and Banks Peninsula catchments - a summary of potential hydro generatiion*

km below the Clyde-Havelock confluence and onto the coastal plains before flowing into the Pacific.

A potential scheme (C42) considered on the Rangitata River is across the gorge upstream of the Rangitata Diversion that would use the drop of around 40 m to generate 40 MW. Another option uses the difference in the elevation between the first length of the Rangitata Diversion Race and the Rangitata River to generate around 32 MW. Another possibility is a 30 MW scheme (C39) on Bush Stream, a tributary of the Rangitata River.

The Ashburton River has two branches. The north branch rises in the Palmer Ranges and flows southeast. The south branch rises in the Arrowsmith Range and flows south and east, combining with the north branch approximately 20 km from the coast. In earlier studies, potential schemes have been identified that could use the difference in level between the South Ashburton – Lake Heron plains and the Rakaia River. Two potential schemes(C40) that would have installed capacities of 27 and 52 MW have been considered, and these would involve diverting the south branch of the Ashburton River to reservoirs formed at Lake Emma or at Lambie Stream.

There is potential for further small generation at the drop structures on existing irrigation canals and the raceways within the district. See figures 2.6 and 2.7. There is a possibility of additional units (~ 6 MW) being installed on the existing Rangitata diversion canal and operated by TrustPower.

http://www.tonkin.co.nz/projects/pdfs/RangitataDiversionRace.pdf

*Irrigation developments*
The existing infrastructure of the Rangitata Diversion Race (RDR) and its associated schemes may be used for future options for Mid Canterbury. There is potential to irrigate a total of 270,000ha, provided there is sufficient storage to increase the supply reliability for existing schemes and irrigate another 80,000ha. Over the years there have been a large number of potential storage sites identified in Mid Canterbury, however in practical terms there were very few options for storing water sourced from Alpine rivers.

The two options currently reviewed were a dam on the south branch of the Ashburton River, referred to as the Stour Dam, and Lake Coleridge. Flow constraints from Lake Coleridge would mean the water could only be used to improve the reliability of water to the RDR.  A total of 20 $m^3/s$ is the most practical flow, but this is not enough to reliably supply 92,000ha.

*Figure 2.6: Source: Ian Bywater*

*Figure 2.7: Source: Ian Bywater*

The Stour Dam could irrigate 90% of the potential area. Priority would be given to existing schemes before water would be used for new areas.

The constraints identified in this district were the equity needed to develop new areas for irrigation and the significant effect storage would have on the flow regimes on dammed rivers. http://www.country-wide.co.nz/article/9153.html

Extra water transported down the plains provides more opportunity for small hydro generation.

An indicative summary of potential hydro generation in the Rangitata and Ashburton catchments is shown in Table 2.8.

### 7 Opihi-Orari and Coastal South Canterbury

There are several rivers that rise in the ranges above the down lands in the region between the Rangitata and the Waitaki Rivers. Most of the rivers in the region were assessed not to have significant opportunities for hydro power development. However a 7 MW scheme has been built at *Opuha Dam* as part of an irrigation project. See 3.1.5 for some details.

*Irrigation developments*

In South Canterbury investigations for irrigation developments have centred around the Opuha and Opihi river systems. A total of 16,000ha is now irrigated by water from the Opuha dam via three separate schemes. Water allocation rules are set by the Opihi River regional plan.

Future options include raising the Opuha Dam by six metres, building storage in the upper Opihi and drawing in-flows from Lake Tekapo. There are various combinations of storage options and race capacities to carry the water from Lake Tekapo. Simply raising the Opuha dam by six metres will not substantially increase the area able to be irrigated in South Canterbury, but it would improve the reliability of water to farmers now on the scheme.

Storage in the upper Opihi would increase the area able to be irrigated by 100% to 33,000ha, as would drawing water from Tekapo, but there are a number of issues and challenges to overcome with both these options, including whether to increase the reliability of water to existing irrigators before bringing in more irrigators. There is also the engineering feasibility of lifting the Opuha dam by six metres to consider.

The key constraints with the Opihi and Opuha system are the lack of in-flows from Alpine rivers which reduces their reliability, and the major constraints with drawing water from Lake Tekapo are the competing demands for that water. http://www.country-wide.co.nz/article/9153.html

The expectation is that further hydro power on a small scale would also be an outcome from such irrigation developments.

An indicative summary of potential hydro generation in the Opihi-Orari and Coastal South Canterbury catchments is shown in Table 2.9.

### 8 Waitaki

Except for the coastal northeast, the region is

| River / Scheme | Capacity (MW) | Remarks |
|---|---|---|
| Rangitata C42) | 40 | |
| Diversion Race | 32 | |
| Bush Stream (C39) | 30 | |
| South Branch, Ashburton | 52 | |
| Canal drop structures | 6 | |
| **Rounded Total** | **160** | |

*Table 2.8: Rangitata and Ashburton catchments - a summary of potential hydro generation*

| River / Scheme | Capacity (MW) | Remarks |
|---|---|---|
| Undefined | ? | |
| **Rounded Total** | **0** | |

*Table 2.9: Opihi-Orari and Coastal South Canterbury catchments - a summary of potential hydro generation*

bordered by highlands on the three sides, which include Hakataramea, Kirkliston, Two Thumb, Ben Ohau, Hawkdun and Kakanui Ranges. The surrounding mountains trend northeast across the path of the rain-bearing winds, and the topography of the region controls the climate and the weather in the area. The upper and mid Waitaki catchments have climates ranging from alpine to sub-continental, while the lower Waitaki climate tends towards sub-humid with cool winters and warm summers. Because of the northwesterly air flows, the upper catchment experiences high rainfall (5000 mm) decreasing to the east (500 mm).

The Waitaki River is the largest river in the region and rises from the Southern Alps. The catchment includes a series of natural lakes, and hydro lakes created for hydro generation. The upper and the middle reaches of the Waitaki River and the associated lakes in the region have been extensively harnessed to produce the bulk of South Island's hydro generation. In the lower reaches, a 900 MW theoretical potential has been deemed possible that would involve several schemes with diversion canal and powerhouse. Meridian Energy's Project Aqua sought to develop a 540 MW scheme, but this was abandoned in 2003 due to uncertainties over the allocation of water. Another scheme, the *North Bank Project* has since been proposed, comprising a 36 km tunnel on the river's north bank with an estimated capacity of 200 MW to 280 MW. The location of the power station has yet to be determined, but it could connect to either the existing Waitaki substation or approximately where the 220 kV Livingstone–Waitaki circuit crosses the Waitaki River. There are no connection issues with either location for connecting the North Bank power station. However, either location may bring forward the need for additional grid backbone capacity within the Waitaki Valley. Meridian Energy has received notification from Environment Canterbury (ECAN) of an interim decision that it has been granted water-only resource consents.

In the 0.5 MW to 50 MW category, a total of sixteen schemes ranging from 1 MW to 14 MW were deemed possible in the Waitaki, including schemes on the lower Waitaki irrigation system. Among them, six that had been considered to be economic would have an installed capacity of approximately 47 MW. The remaining schemes would have a capacity of around 15 MW.

More recent proposals include:

- From the Electricity Commission 2008 Grid Planning Assumptions: Draft generation scenarios Pukaki Control Gate Retrofit (2014, 44 MW)
- There is a concept (Water from West to East) proposal to divert water, from high elevation catchments west of the Main Divide with annual rainfall of over 8000 mm, through tunnels (3.5 m diameter) to a power station (22 MW) near the airport at Mt Cook. See Figure 2.8 and 2.9.The diverted water then passes through 6 or more further power stations. See Figure 2.10. Based on a flow rate of 20 $m^3/s$, this extra diverted water is estimated to produce 450 GWh annually. This can be compared with the storage in Lake Pukaki at 1679 GWh. (*Water: From West to East* by Norman Hardie in Constructing New Zealand, Feb 2009)
- A further concept proposal (Project Dustorm) is for increased hydro storage at Lakes Tekapo & Pukaki. A schematic representation of the proposed Project Dustorm is shown in Figure 2.11. Water storage has value in that the water would otherwise be spilt and not be used for generation. The project offers:
  - Extra 5% storage in both lakes without affecting the containment structures.
  - Lake-heads returned to the pre-hydro 'natural' condition.
  - Permanent fix for Tekapo dust storms – allowing better use of existing storage.
  - Low cost 500 GWh strategic reserve.
  - Invisible on completion.
- New large scale hydro and/or irrigation storage would also allow value to be created during times of excess wind and hydro spill. However there is no provision in the Waitaki District Plan to permit the construction of a suitable transmission line i.e. it would be a non-permitted activity. There are many locations in the Waitaki district suitable for building large scale

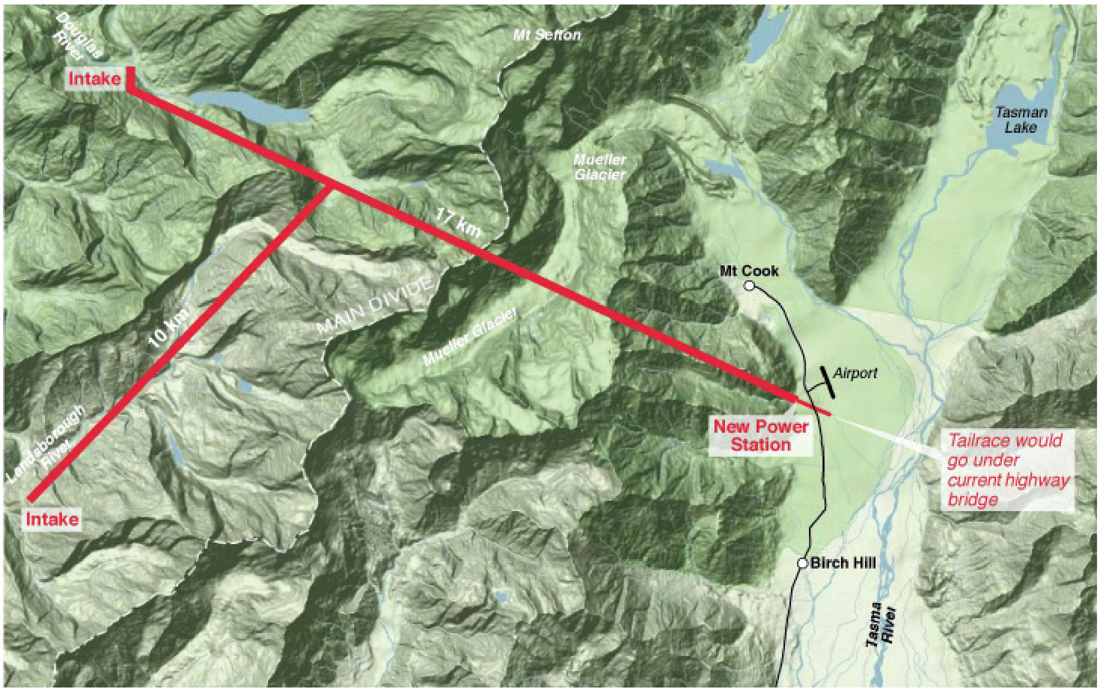


*Figure 2.8: Water from West to East, proposed tunnel alignements*

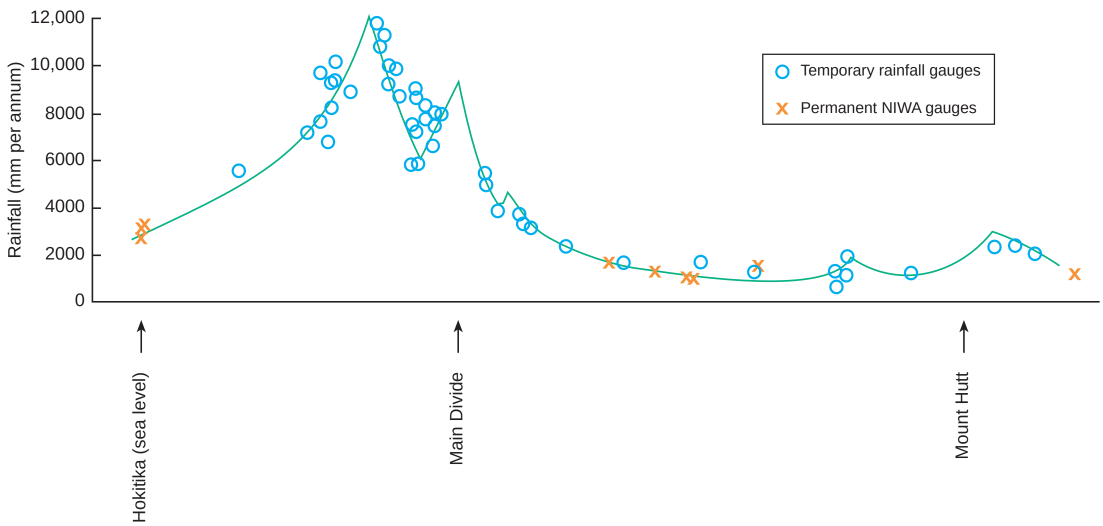


*Figure 2.9: Transect showing distribution of rainfall*
*(Source: The New Zealand Journal of Science 1983, Vol. 26)*

hydro storage that can be applied to both irrigation and electricity security. Pumped storage to use excess energy should not be overlooked. Pumped storage is used when there is little control over the availability of generation such as wind or when base load generation has limited ability to back-off such as thermal and nuclear plants. Pumping allows them the run at optimum level over night and the storage is used for peaking during the day (Waitaki Report Dec 2008).

An indicative summary of potential hydro generation in the Waitaki catchments is shown in Table 2.10.

### 2.1.5 Summary

Rounded totals for the remaining potential hydro capacity (MW) for each of the eight catchments have been shown above.  The sum of the rounded totals is 3590 MW.  Much of this will be in the too hard basket, or not economic.  The section 1.7 Barriers to Renew-

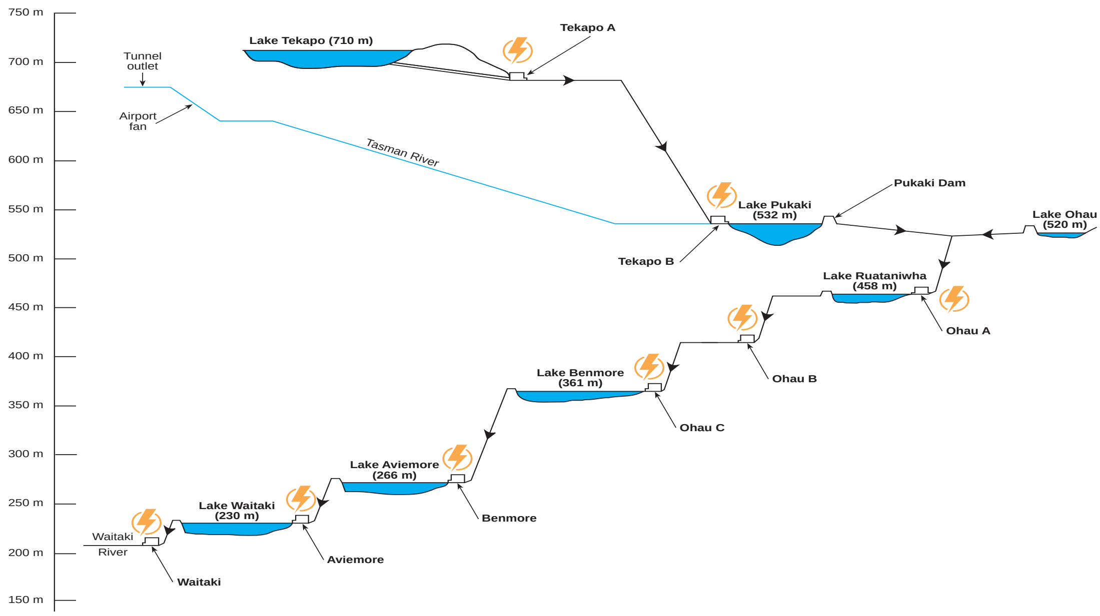


*Figure 2.10: Schematic representation of the proposed Water from West to East project (not to scale)*

able Energy is particularly relevant for realistic consideration of these potential developments.

Schemes that combine hydro and irrigation are more likely to have better prospects.

## 2.2 Marine Energy Resources: Wave/Tidal Power

### 2.2.1 Marine Energy report

Planners and developers seeking to understand the potential for marine energy development around New Zealand, have a new resource providing a comprehensive analysis of wave energy around the coast, as well as an in-depth analysis of selected wave and tidal hotspots.

A report "Development of Marine Energy in New Zealand" prepared for the Electricity Commission, the Energy Efficiency and Conservation Authority, & Greater Wellington Regional Council by Power Projects Limited, 30 June 2008, is available at http://www.eeca.govt.nz/eeca-library/renewable-energy/marine/report/marine-energy-in-nz-jun-08.pdf.

Maps and data graphically illustrate New Zealand's marine energy potential, and it is notable that nearly the entire west coast has, by international standards, a viable wave

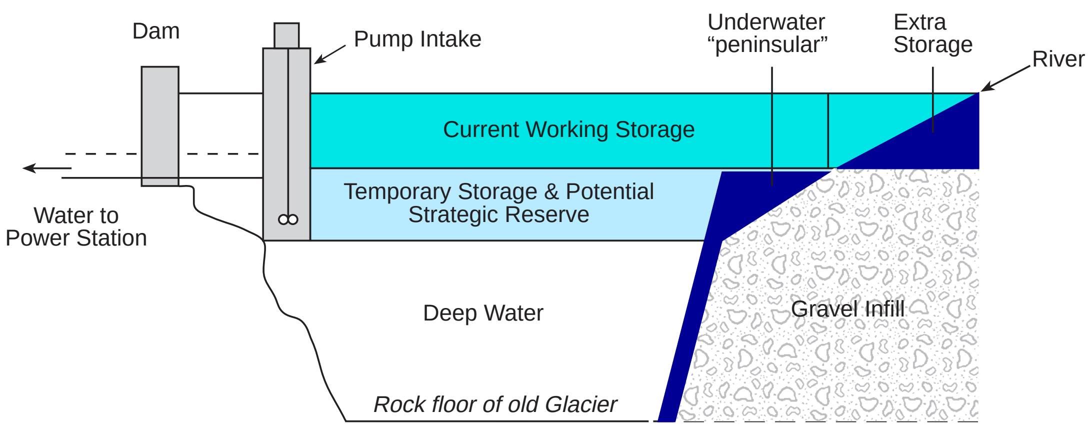


*Figure 2.11: Schematic representation of the proposed Project Dustorm*

| River / Scheme | Capacity (MW) | Remarks |
|---|---|---|
| Pukaki Control Gate Retrofit | 44 | 2014 Hydro, backed by storage |
| Lower reaches Waitaki | 700 to 620 ? | 900 MW potential incl North Bank |
| North Bank Project | 200 to 280 | Granted water-only resource consents. Operating 2015? |
| 6 small schemes | 47 | Considered economic |
| 8 other small schemes | 15 | Potential |
| Water: From West to East | 22? | "New" water 20m$^3$/s |
| Project Dustorm | ? | Increased storage in Tekapo & Pukaki |
| New large scale storage | ? | For irrigation and hydro |
| Pumped storage | 100? | Undefined location: 2030, 2035 |
| **Rounded Total** | **1100** | |

*Table 2.10: Waitaki catchments - a summary of potential hydro generation*

resource. What's more, generally being within 5 to 15 km of the shore, the wave resource is reasonably accessible for development. Whilst the east coast (Canterbury) experiences large wave events, lower average wave energy flux than the west coast mean it will be less viable for development.

In modelling the theoretical power outputs of two types of wave devices and providing a detailed resource overview, the report aims to help developers and planners to marry what a location offers with the available devices, or direct device design to meet the New Zealand opportunities. Devices must be built or selected based on location specific marine energy profiles. Different devices need different ranges of wave heights, wave lengths and orbital velocities for optimal power generation. They will also require different wave conditions to enable servicing. Some devices designed for European conditions, for instance, may not be suited to the NZ west coast environment.

New Zealand also benefits from high energy tidal flows. The map of Cook Strait tidal hotspots vividly illustrates that energetic locations are conveniently located for the Wellington region on the North Island side of the Strait. http://www.metocean.co.nz/cms/node/300

### 2.2.1 Marine Energy Activity

The pace of domestic marine energy activity has picked up since 2006 with the deployment of the first experimental wave energy converter (WET-NZ device), the grant of the first consents for an in-stream tidal prototype (Neptune Power) and the award of $1.85 million from the Marine Energy Deployment Fund (MEDF) to Crest Energy for its proposed tidal stream project in Kaipara Harbour, subject to grant of a resource consent for the project.

The pace of international marine energy precedes domestic developments. Verdant Power has installed and operated six 35 kW tidal turbines in the East River of New York since 2007. Ocean Power Technologies has had a 40 kW PowerBuoy working continuously off the New Jersey coast for over 2 years now. More recently, the first full-scale tidal stream demonstrator, the Marine Current Turbines' SeaGen device was deployed in Strangford Lough, Northern Ireland, in April 2008. Pelamis Wave Power reports that its long-awaited Pelamis deployment of 3 Pelamis devices at Aguçadoura, off Portugal, were commissioned in 2008, with peak output 2.25 MW.

### 2.2.3 Marine Energy Sources.

Of all the marine energy sources, wave and tidal/ocean current energy have the best potential for providing power to New Zealand in the future. Wave devices seek to harness either breaking waves or open-ocean swells, whilst tidal devices extract energy from either tidal rise and fall or tidal currents. Ocean thermal energy, osmotic power and marine biomass may have future potential but technologies to harness these energy sources are at an early stage of development.

In Power Projects' view it is premature to attempt a total forecast for the capacity of marine energy in New Zealand. The large range of estimates made by others (‹10,000 to 30,000 MW for wave) serves to demonstrate the difficulty of doing such an assessment. In any event these are estimates of the potential resource and not the likely recoverable reserves, *i.e.,* the total capacity of the economic projects, are likely to be considerably lower than these very large figures.

Whilst these very large estimates may also serve to promote marine energy, they set an unrealistic expectation of the likely size and timing of the contribution of marine energy, which may ultimately discredit the nascent industry. A more measured approach is justified: identifying regional wave and tidal/ocean potential, by integrating resource data and device performance data to derive potential project capacity (in MW) and annual generation capacity (in GWh/year).

There is a generally accepted '*rule of thumb*' for wave energy projects, which will assist an understanding and evaluation of Figure 2.12 showing the mean spectral wave power, of the wave resources. A mean spectral wave power of greater than 20 kW/m in an area indicates potential for wave energy projects there. The actual requirements of a particular site are clearly much more detailed. The contour at 20 kW/m is a significant distance from the Canterbury coast.

http://www.eeca.govt.nz/eeca-library/renewable-energy/marine/report/marine-energy-in-nz-jun-08.pdf June 2008

### 2.2.4 Summary of Marine Energy Resources: Wave/Tidal Power

- SKM estimate that with a Canterbury

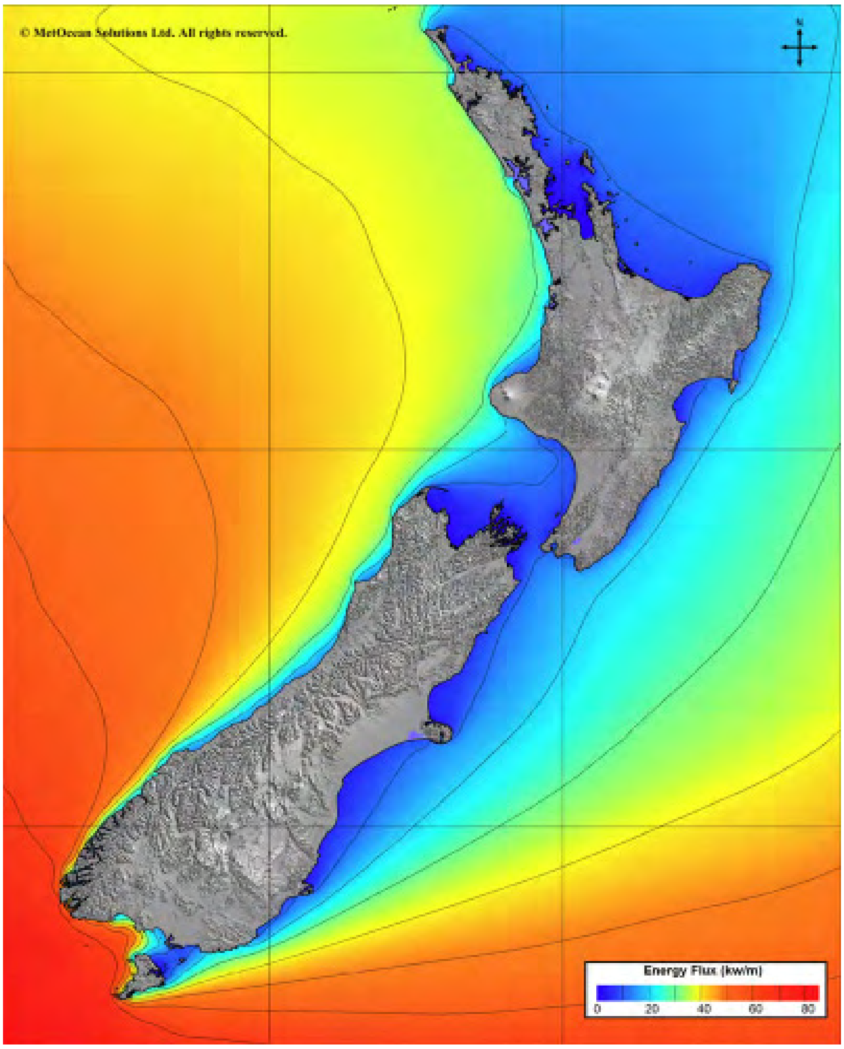


*Figure 2.12: Mean spectral wave power (1998-2007)*

coastline length of around 400 km, a capacity potential from wave energy in the **thousand megawatt range**, ignoring environmental constraints and conflicts with other marine users. The west coast and Southland have significantly more energetic sites close to the shore.

- There are currently no identified significant opportunities for tidal current devices on the Canterbury coast.

## 2.3 Geothermal

### 2.3.1 Energy in ground at ambient temperature (non-geothermal)

The energy in the ground at ambient (non-geothermal) temperatures (10-15˚C in New Zealand) represents a significant energy resource and can be used with ground source heat pumps (GSHP) (see Figure 2.13). This technology is used on a large scale in North America and Europe where the climate, high electricity prices and subsidies make this technology economic. These drivers are largely absent in New Zealand and as a result there has been little use of GSHP's in New Zealand. Use of geothermal heat using ground source heat pumps can save up to 60% on electricity heating costs in a typical New Zealand home but, because of the high installation cost (approximately NZ$12,000), may only be economic in larger commercial buildings and greenfield sites, due to the area and preparation required. (SKM 2006)

### 2.3.2 Geothermal sites in New Zealand

Hot water springs and pools occur in many places throughout the country, usually associated either with recent volcanic activity, or with active faulting. Wells and hot springs are shown in Figure 2.14 and locations of known warm water occurances in Figure 2.16..

### 2.3.3 Conventional geothermal systems

These contain naturally occurring hot water in porous and permeable rocks, which are also referred to as hot wet rocks or hydrothermal systems. A special type of groundwater provides electricity and heating - geothermal steam. In areas of recent volcanic activity where the ground is still hot, groundwater

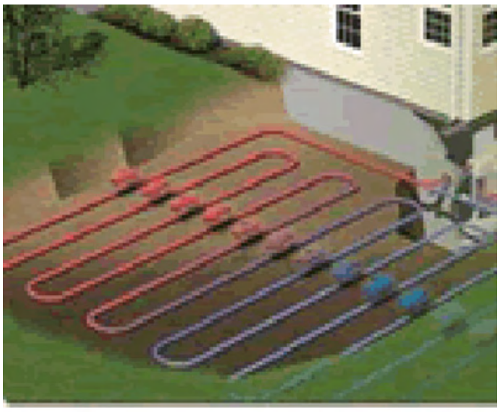

*Figure 2.13: Ground source heat pump*

temperatures may exceed boiling point. When wells are drilled into the water-bearing strata, the superheated water is discharged under great pressure. The system is recharged by rain and surface water percolating through the hot rocks. See Figure 2.15. A steam field at Wairakei is exploited for electricity generation, other fields nearby and in Northland have the potential for development. Geothermal steam is used directly by industry at Kawerau, while many factories and homes use hot water for central heating in Rotorua and Taupo. Over-use can deplete geothermal fields, and may cause ground subsidence.

### 2.3.4 Canterbury Resources

Banks Peninsula is formed from ancient volcanoes, but there is no longer any volcanic heat flow underneath them. Warm springs (less than 70˚C) are found in non-volcanic areas of New Zealand. Faults – deep fractures in the rock – provide channels for warm water to rise rapidly from depths where it has been heated. Striking examples are the hot springs aligned along the Hope Fault, in North Canterbury, and the Alpine Fault, in the Southern Alps. At Hanmer, near the Alpine Fault, a range of thermal pools attract thousands of visitors every year.

## 2.4 Wind

### 2.4.1 New Zealand Wind Farms

New Zealand has eight operating wind farms. These wind farms have a combined installed capacity of 325 megawatts. They supply about 2.5% of New Zealand's annual electricity


*Figure 2.14: Map of New Zealand Geothermal Fields*

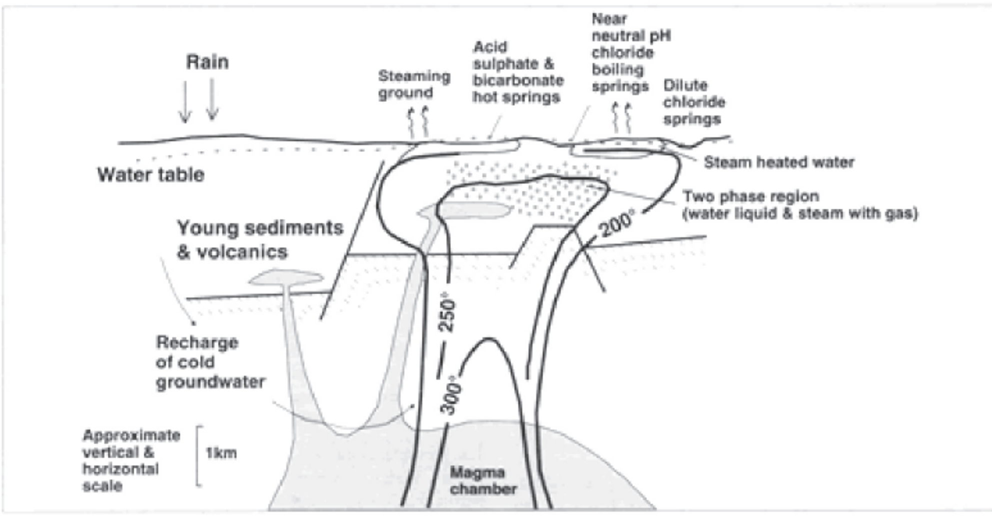


*Figure 2.15: Generalised Geothermal System of the Taupo Volcanic Zone*
(After Henley & Others, 1986)

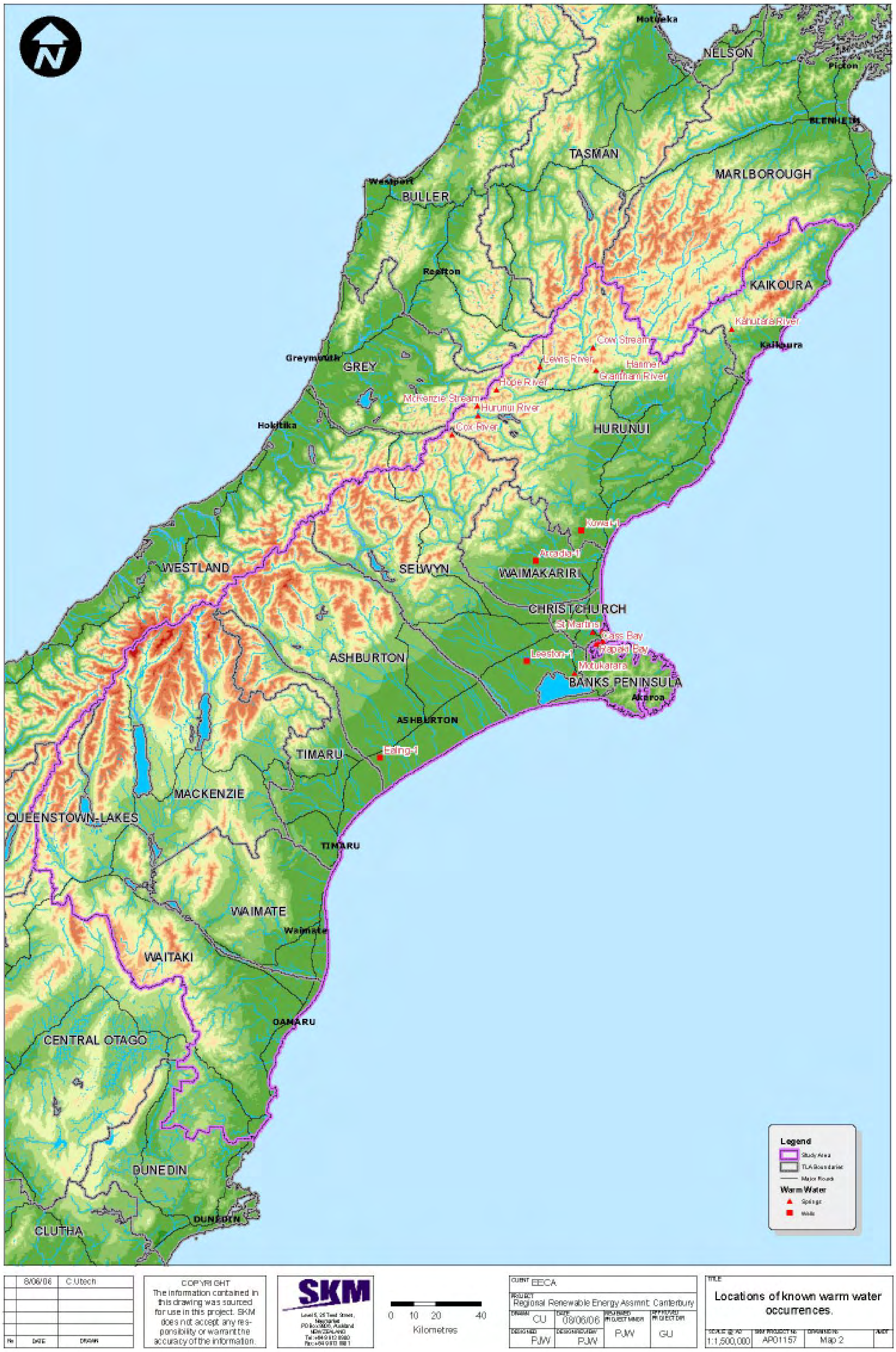


*Figure 2.16: Locations of known warm water occurrences (Springs & wells)*

generation (1040 gigawatt hours in the year to March 2008), which is about the same amount of electricity as 145,000 New Zealand homes use in a year. Canterbury has two wind turbines as identified in Table 2.11 of New Zealand Windfarms (Feb. 2009).

Wind farms that have been subject to consentng process but are not yet commissioned have a total power of 1768 MW (excluding projects abandoned and declined) (see Appendix E).

Wind farms at investigation stages (25 projects) have a total power of 1129 MW.

### 2.4.2 Wind Resource

Overall, New Zealand has good wind resource due to its location in the roaring forties, but wind speeds vary considerably around the country. Both wind resource maps in Figure 2.17 have limited accuracy but provide a good indication of high wind areas. The NIWA map is derived from met station data whereas the Canterprise map is based on weather model data.

It is not only the wind speed that determines suitable areas, but a range of other factors including location of important natural features, proximity to population, site availability, topography, access and distance to electricity network or grid.

Figure 1.21 in Section 1.7 shows areas that will require careful and sensitive planning when proposing wind farms. Applications for siting of wind turbine units or larger farms in native

| Wind farm | Operator | Region | Wind farm capacity (MW) | Turbines | Date commissioned | Turbine capacity (MW) |
|---|---|---|---|---|---|---|
| Brooklyn | Meridian | Wellington | 0.225 | 1 | 1993 | 0.225 |
| Gebbies Pass | Windflow | Canterbury | 0.5 | 1 | 2003 | 0.5 |
| Hau Nui | Genesis | Wairarapa | Total: 8.7 | 15 | | |
| | | | *Stage 2: 4.8* | *8* | 2004 | 0.6 |
| | | | *Stage 1: 3.9* | *7* | *1996* | 0.55 |
| Southbridge | Energy3 | Canterbury | 0.1 | 1 | 2005 | 0.1 |
| Tararua | TrustPower | Manawatu | Total: 161 | 134 | | |
| | | | Stage 3: 93.0 | 31 | 2007 | 3.0 |
| | | | Stage 2: 36.3 | 55 | 2004 | 0.66 |
| | | | Stage 1: 31.7 | 48 | 1999 | 0.66 |
| Te Apiti | Meridian | Manawatu | 90.8 | 55 | 2004 | 1.65 |
| Te Rere Hau | NZ Windfarms | Manawatu | Operating: 6 | 12 | 2006 | 0.5 |
| | | | Under construction: 42.5 | 85 | 2008/2009 | |
| White Hill | Meridian | Southland | 58.0 | 29 | 2007 | 2.0 |
| West Wind | Meridian | Wellington | Under construction: 142.6 | 62 | 2009 | 2.3 |
| Horseshoe Bend | Pioneer Generation | Central Otago | Under construction: 2.25 | 3 | 2009 | 0.75 |
| **Total operating** | | | **325.3** | **248** | | |
| **Total** | | | **512.65** | **398** | | |

*Table 2.11: New Zealand Wind Farms (Feb 2009)*

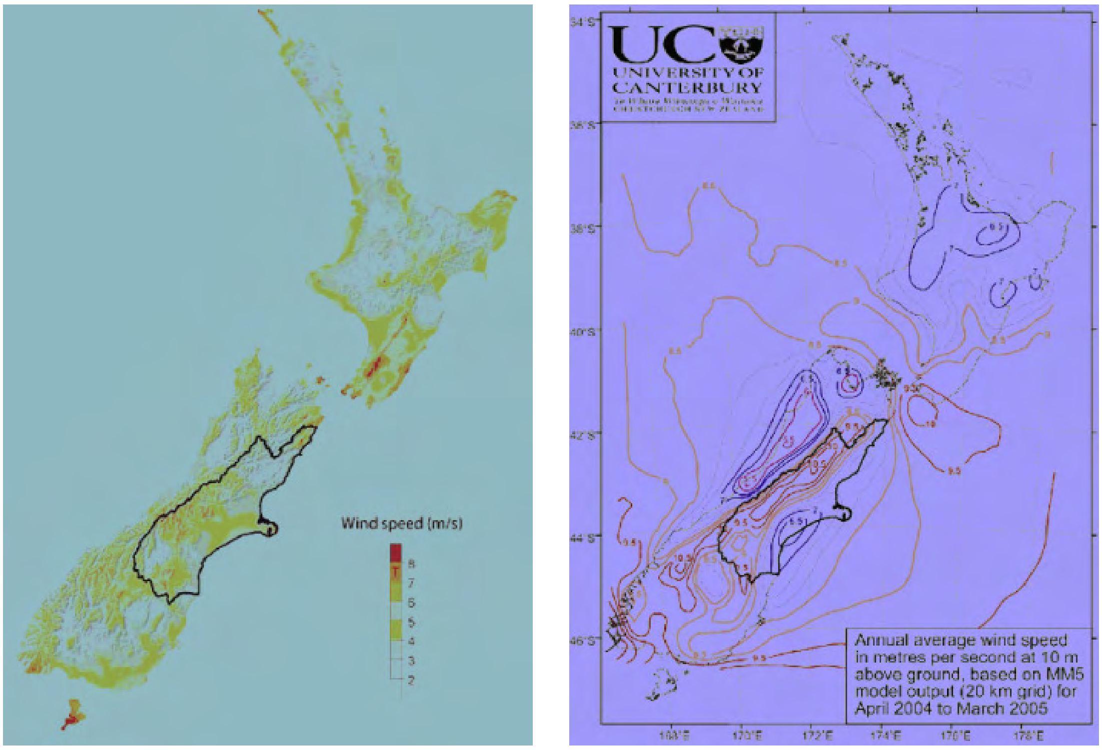


*Figure 2.17: Median and average wind speed at 10 m height (NIWA 2005a, Canterprise 2005)*

forest or on Department of Conservation (DoC) land can be subject to a lengthy and complicated consenting process. Most of these areas are currently perceived as not suitable for wind farms. It can be seen that it may be difficult to obtain consents for some elevated and exposed areas with likely higher wind speeds.

At this stage it is difficult to predict if very large wind farms (300+ MW) are likely to be developed in the region. Due to the population density in the Canterbury plains and along the coast, large wind farms would need to be developed in more remote places inland. There seem to be no suitable large ridgelines which could be used that are comparable to the Tararua Ranges or the Te Waka/Maungaharuru Ranges (Hawke's Bay). The wind farms in the Canterbury region are expected to be in the 50-150 MW range, and located some distance from each other so that cumulative effects, primarily adverse visual impact, are less likely. Five to ten wind farms of that size could potentially be developed based on an initial screening of the region taking into account wind resource, topography, population density, distance to grid, accessibility and environmental factors (e.g. native forest and DoC land). Maps 3 and 4 in Appendix C show topography, infrastructure and native forest/DoC land in more detail than Figure 1.2.1.

At current market conditions a lot of the potential wind farm sites in the region are probably only marginally economically viable. Rising electricity prices are likely to change this in the near future though.

The development of wind farms in the Canterbury region is likely to cause some controversy as it does in other regions of the country. If carefully planned, approximately 1000 MW of wind capacity could be installed over a number of years with environmental impacts that are broadly acceptable to local communities. The technically available potential is much larger.

The development of wind farms in the Canterbury region needs also to be looked at in a nationwide context. Due to the intermittent nature of wind power there is a limit to how much wind power can be connected to the national grid. A study investigated the wind power integration limit (Energy Link & MWH NZ 2005). It was found that 20% of the nation's annual electricity consumption could potentially be met by wind generation. This leads to a potential wind power capacity of around 2,000 MW (based on today's consumption).

**Waitaki District Wind Example**

The Waitaki District has a very large site suitable for wind farm development on the Kakanui Ranges. (The Kakanui Ranges are partly on the boundary with the Otago Region) The wind resource modelling undertaken by University of Canterbury for Network Waitaki Ltd (NWL) shown in Figure 2.18 indicates the scale and quality of the resource.

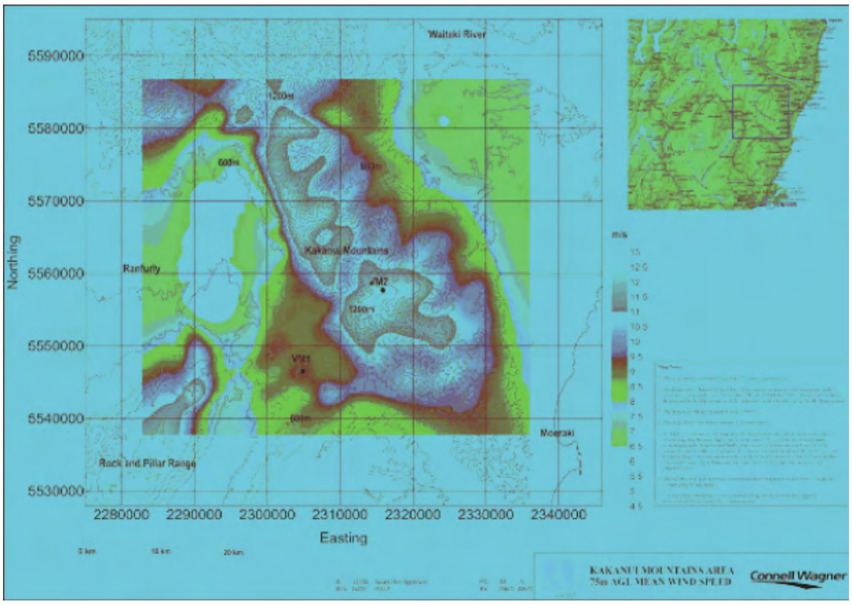


*Figure 2.18: Scale and quality of the wind resource*

This opportunity is larger than can be connected at distribution network level but is relatively close to the Rox- Liv 220kV transmission line which crosses the same range through Dansey's Pass. To realise this opportunity requires a portfolio of other generation such as hydro to secure supply when the wind is not blowing. Wind generation can add value to hydro generation in the reciprocal scenario. Large scale hydro storage and/or irrigation would also allow value to be created during times of excess wind and hydro spill. There is no provision in the District Plan to permit the construction of a suitable transmission line i.e. it would be a non-permitted activity.

There are an equal number large scale hydro storage sites that can be developed in the district. In fact there is a wealth of diverse generating resources that would benefit the community to supply all its own energy, secure that supply, derive more income from being a net exporter of energy (and retain the profits locally), and decouple itself from the rising electricity price path being delivered by the national system.

The issue that prevents this opportunity being developed is scale and local capital resources. If these opportunities are to be developed then the community needs to find a mechanism for securing a share of the benefits.

**Waitaki District Plan**

Currently, even such small scale generation of any type is not a permitted activity in the Waitaki District Plan. A set of development rules, within which such a proposal must comply, would be more helpful for such developments. It is a fact that windy sites tend to be on hill tops where they are visible. The blanket nature of Significant Landscapes District Plan Changes is creating uncertainty with regard to where value judgements will rest and the cost of the consenting process. The community is still debating issues around landowners' rights and whether wind turbines alter the developed farmland character of sites. [Energy Sustainability Plan - Waitaki District 2008]

There is currently 325 MW of wind power installed in NZ but a number of large projects totalling approximately 2900 MW are under way or are being planned. Small scale wind turbines (<10 kW), which are used for remote power supply, can successfully be operated in areas with lower wind speeds also. However, the lower hub heights (approx. 10-20 m) of these smaller turbines means more care needs to be taken when siting near local obstacles (*e.g.* trees and buildings). Small scale wind turbines are not expected to play a significant role in future electricity generation, but they can become important for remote farms and settlements. (EECA)

### 2.4.3 Inland Canterbury Wind Sites

Wind maps show that inland Canterbury has good wind resources and, therefore, has the potential for wind generation. However, most of the area is distant from significant transmission. http://www.gridnewzealand.co.nz/f41,2256/2256_canterbury-regional-plan.pdf

### 2.4.4 Medium scale wind sites

Wind is also viable at a smaller distributed generation scale. That is, small wind farms up to a few MW in capacity, with up to 3-4 turbines. Viability results from smaller scale allowing lower quality wind resources to be used which are located closer to existing electricity networks and so avoid the need for expensive network upgrades. Further the risk is lower and so less effort is required to monitor wind before development. Second hand wind turbines are readily available for this type of rapid implementation development. The total number of these sites exceeds the need from local use perspective. Approximately 30MW of wind generation is estimated to be adequate from an optimal system perspective. This scale of development is well within the scope of farming business to fund and could be used in the future to off-set power charges. In this scenario the diversity in the load of the all consumers connected to the distribution system, in effect allows surplus energy to be stored and used later i.e. only net flows flow into the distribution network. The more distributed generation connected to the network the lower the use of the transmission system and the cost for doing so. If surplus generation eventually results into a net flow back into the transmission system then the system adds value to the energy being exported.

### 2.4.5 Summary

1 If carefully planned, approximately 1000 MW of wind capacity could be installed in Canterbury over a number of years with environmental impacts that are broadly acceptable to local communities. The technically available potential is much larger.

2 There is potential for medium scale generation close to existing electricity networks.

3 See Section 3.4.6 for domestic scale wind turbine systems.

## 2.5 Solar

### 2.5.1 Solar Resource in the Canterbury Region

Solar radiation across New Zealand is similar to that at many sites in Australia and higher than most areas in Europe (Table 2.12). Solar radiation for the Canterbury Region is approximately 1350 kWh/m$^2$.yr, with no large variations across the region (Figure 2.19). (SKM 2006)

However, the area near Lake Tekapo is one of a few places in New Zealand where solar radiation is greater than 15 MJ/m$^2$.day (5475 MJ/m$^2$.yr) which is more than Melbourne (5302).

The solar radiation varies greatly over the year. Figure 2.20 shows the variation at 13 weather stations in the region. The given radiation data is valid for horizontal surfaces. The gain of solar systems can be easily enhanced by tilting the system towards north. Optimum tilting angle is the value of the latitude of the site. For example, an increase in the performance of a solar system in Canterbury of around 12% can be achieved by tilting the system by 45° towards north. (SKM 2006)

### 2.5.2 Potential for Solar Thermal (Solar Water heaters)

Households account for 42% of electricity demand in the Canterbury Region (EECA,

| | MJ/m²/yr | kWh/m²/yr |
|---|---|---|
| **Sydney** | 6150 | 1708 |
| **Melbourne** | 5302 | 1473 |
| **Kaitaia** | 5288 | 1469 |
| **Hamilton** | 5157 | 1433 |
| **Gisborne** | 5386 | 1497 |
| **Blenheim** | 5230 | 1453 |
| **Christchurch** | **4898** | **1360** |
| **Invercargill** | 4652 | 1292 |
| **Germany** | 3609 | 1003 |

*Table 2.12: Typical values of total global solar radiation for several sites (EECA 2001b, NIWA 2006a)*

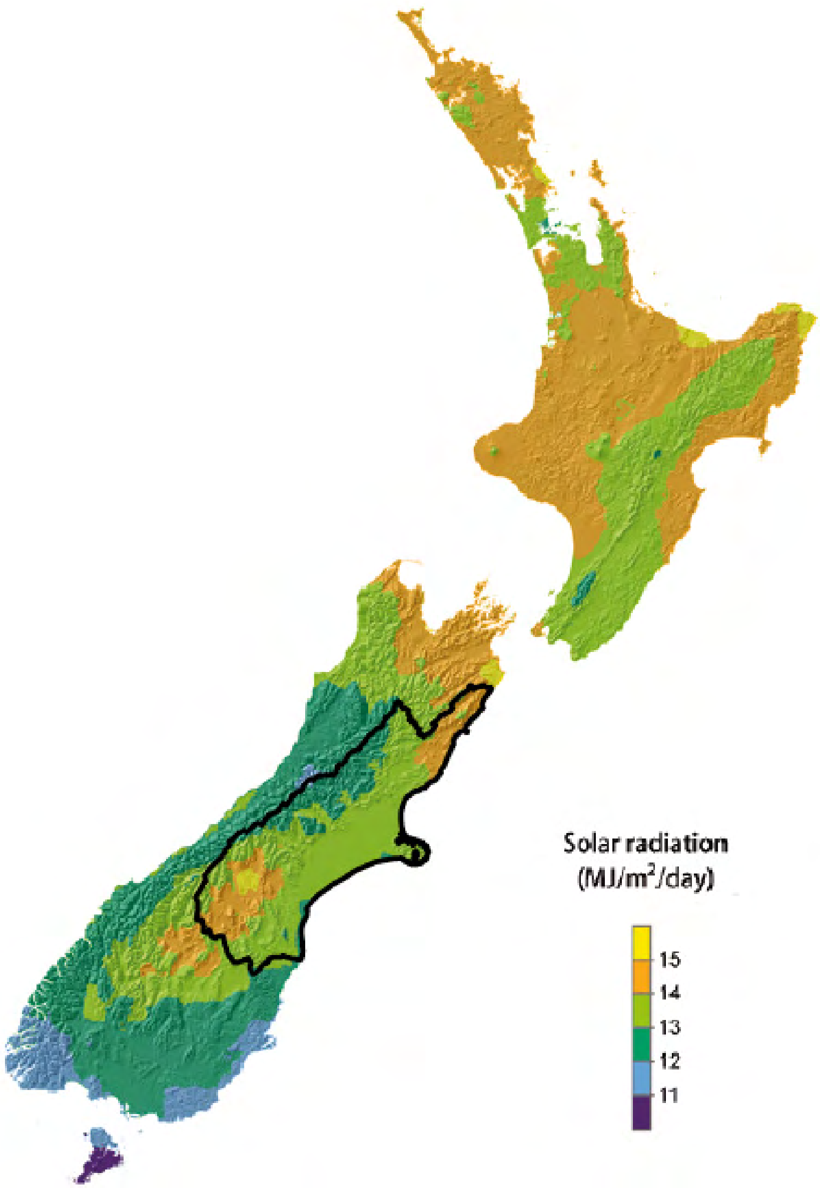


*Figure 2.19: Solar radiation distribution (NIWA 2005b)*

2004). Of this, about one third is usually for water heating (BRANZ 2004). A standard solar thermal system can produce around 55% of a household's water heating. Hence, the installation of solar thermal technologies has the potential to address some of the region's overall supply issues. Solar thermal systems are most economic when installed in new buildings. The areas with high demand in new housing are best suited for promotion and installation of solar thermal systems. Overall, *there is potential for a substantial increase in the uptake of solar thermal use in the Canterbury region.*

### 2.5.3 Potential for Solar Photovoltaic

The biggest barrier for the large scale uptake of PV is the high cost of the technology. Consequently, uptake has predominantly been for remote power supplies, enthusiast users and commercial developments where renewable energy has additional value as a corporate strategy or image statement. In summary, *the current high costs of solar photovoltaic means that large scale grid connected uptake in the region is unlikely in the short term, however small scale applications, particularly for remote power supply are expected to become more popular.* This is discussed further in Section 3.5.5.

### 2.5.4 Potential for Passive Solar Building Design

Solar space heating can significantly reduce the amount of energy use in new buildings. With solar space heating, the building is designed to optimise the absorption of solar energy. This solar space heating can be applied to any building regardless of size or use (domestic/commercial). The building design considers building placement and orientation on the site and design features to capture, store and release solar energy in the building. Solar building design not only reduces otherenergy use, but it also can reduce moisture and condensation, improve sound insulation and provide a generally more comfortable and healthy living environment.

### 2.5.5 Solar access

- A case study of residential land development was analysed in terms of its potential for energy efficiency gains and optimisation of solar resources. A design tool was developed to assess the solar energy loss of a specific building site due to existing

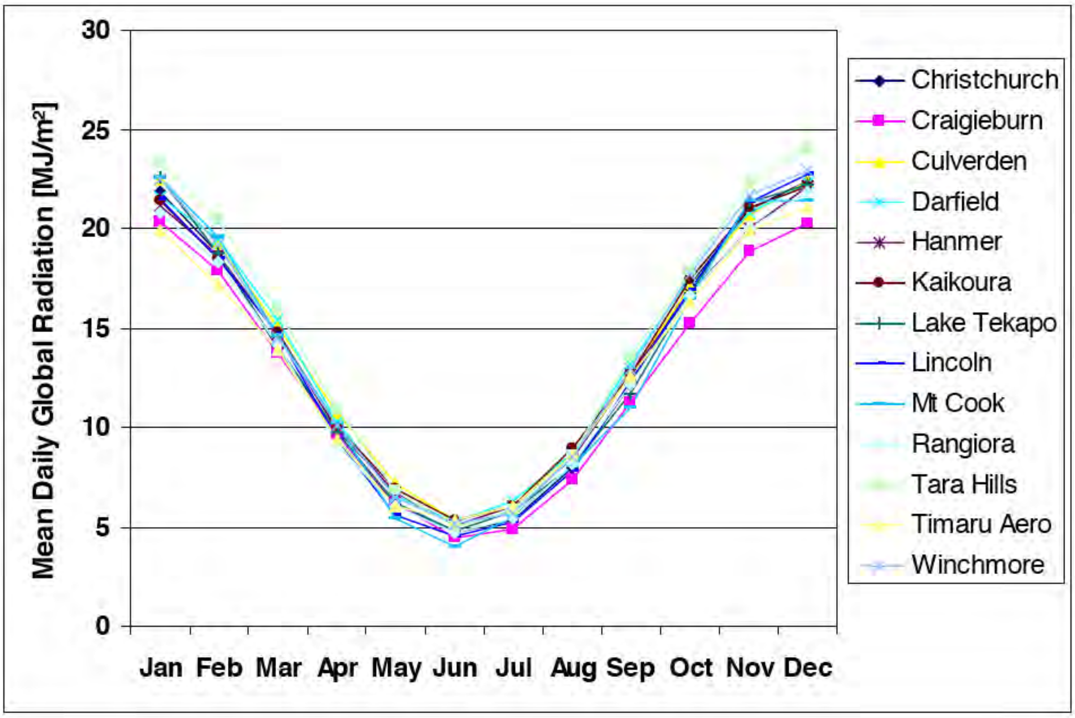


*Figure 2.20: Monthly variation of solar radiation (NIWA 2006a)*

land features. The tools developed can be used to optimise the design of a residential land development resulting in a decrease in energy use compared with standard residential developments. The study concluded that incorporation of the tools as standard practice by municipalities is viable, and if implemented would increase the energy efficiency of the New Zealand housing stock. http://www.nzsses.auckland.ac.nz/conference/2007/papers/DUNCAN-Solar%20design%20tools.pdf

- There is a need for local authorities to address solar access issues, particularly in high density housing areas. http://www.sef.org.nz/papers/sef_hw_hvac_sub.pdf
- As sustainable development becomes a more important outcome at a local and national-level, district plans will need to be modified so that they take a more positive approach to the promotion of sustainable development practices.

Sustainable development elements are beginning to be addressed with regard to intensive development. District plans are beginning to require site analysis at the beginning of the design process to ensure that development responds to the natural features, opportunities and constraints that exist within a site. Assessment criteria may refer to the extent that sustainable building practices are followed. Generally, these types of provisions are being applied because comprehensive redevelopment of sites to a higher density enables sustainable development features to be considered in an integrated way.

- **Nuisance Trees.** Nobody may interfere unreasonably with other people's use and enjoyment of their land. This means that you are responsible for ensuring your own trees do not cause problems for anyone else. A nuisance may be by blocking sun or light. Claims for more than $7,500, or that involve the loss of light, sunshine or views, or that involve the removal or trimming of trees, can be taken to a district court. The court can award monetary compensation for damage caused by a tree. It can also order that a tree be removed or trimmed. Claims through the District Court will almost certainly require the help of a lawyer and can be expensive.

This is a general problem: typical District Plan protection is inadequate for a house designed to rely on passive solar heating. District Plans typically require a house to be inside a building line rising vertically to 2.0 m at a point 0-3 m inside the boundary line, and then sloping inwards at 45° (recession plane) to some specified maximum height. This gives little protection when the noon winter sun is only 26.5° above the horizon, and no protection against growing trees.

Molly Melhuish points out that the city of Boulder, Colorado, has addressed this problem (Boulder is in latitude 36°, compared with Auckland 37°, Dunedin 46°). Their guidelines are on the web at: http://www.ci.boulder.co.us/buildingservices/guides/solrshad.pdf.

Broadly, Boulder offers:

- planning requirement for new houses to be built with their long axis E-W, with subdivisions laid out accordingly. There are additional requirements for sloping ground.
- General protection of a right to sun for a minimum of four hours (11:00 – 14:00) in mid-winter.
- Special protection for houses designed for solar gain, buy issuing a 'solar access permit'.

*EnergyWatch 36*

## 2.6 Wood (Biomass)

Forests will play a pivotal role in the development of a bio-based economy. www.scionresearch.com

Canterbury is a relatively small player in the NZ forestry sector despite having a considerable forest estate with only 6.3 percent of NZ's total forest estate.

The extent to which future forest conversions occur will be very dependent on the further development and availability of irrigation. The Peer Review posed the question, "Do the government's greenhouse policies impact on the ability of landowners to convert forestry to dairy?" This question should be investigated further in a RSOO as the issues involved may have a large bearing on the future direction of the forestry industry.

### 2.6.1 Possible barriers to investment

Investment in trees and forests will be affected by uncertainty about how demands for environmental services will be transmitted through regulators' policies at the international, central, and local government levels.

Other domestic barriers include:

- the lack of integration between farming and forestry, with the exception of farm-foresters;
- the potential for poor returns that would discourage investors; land use controls in parts of many districts that require consents for tree planting;
- difficulties with obtaining consents under the Resource Management Act 1991 (RMA) for developing supporting wood processing facilities;
- issues and/or perceptions about the stability of the electricity supply. http://www.maf.govt.nz/forestry/publications/future-drivers/future-drivers-for-new-zealand-forestry.pdf

### 2.6.2 Wood as a renewable resource

Image and perceptions are important. Wood has a great story to tell as a renewable resource with relatively low embodied energy. In New Zealand, the NZ Wood programme (jointly funded by industry and government) has begun to tell this story, though to firmly secure wood's place in the national psyche, a multiyear campaign is required.

### 2.6.3 Plant-based biomaterials and bioenergy

The transition from products derived from fossil fuels to the energy derived from sustainable resources provides exciting opportunities for plant-based biomaterials and bioenergy.

Biomaterials currently being investigated in New Zealand include bioplastics, biofoams, moulded structures and packaging, and composites (wood-plastics and wood-steel). However, the biomaterials industry is still in its infancy with substantial research and evaluation to complete on processes and economics. It may be 20 or 30 years before biomaterials add significantly to forestry returns.

Also under investigation are further opportunities for converting wood fibre into energy and biofuels. As costs are imposed on greenhouse gas emissions from the use of fossil fuels, economic drivers will increasingly favour bioenergy, including solid wood energy such as wood pellets, biomass gasification, and ligno-cellulosic ethanol. Oil prices, energy security, and climate change concerns are already driving innovations such as torrefaction, bioenergy and biochar co-production, and potentially cellulignin.

The use of wood fibre for production of biofuels and speciality chemicals is being seriously researched in New Zealand and elsewhere. However, the recent conversions overseas of arable land from producing food to producing biofuels have generated global controversy and some uncertainty about biofuels.

Trees are being seen as chemical warehouses rather than just wood and fibre. (www.scionresearch.com)

### 2.6.4 Harvesting over the next 20 years

For the next 20 years, both the quantity and the quality of the wood that will be harvested have been set by the forests already established and by their management. However, development of some very short-rotation crops for bioenergy production may be possible.

Barring physical (wind) or biological (establishment of a major pest or disease) disasters, New Zealand can expect that the annual quantity of wood available for harvesting will increase by around 10 to 11 million cubic metres by 2020, or 50 percent more than the current annual harvest. This increase does not mean all the additional wood will actually be harvested. The amount harvested will be determined by the availability of markets that provide acceptable returns to producers, and possibly by carbon prices, which may encourage "carbon farming" rather than tree harvesting. Also impacting on markets will be competition from overseas producers and from alternative (non-wood) products.

### 2.6.5 Effect of the emissions trading scheme on forestry

The emissions trading scheme (ETS) could significantly change the forest growing industry. Participants in the ETS may shift to long-lived, high-volume species such as Douglas-fir, redwoods, and eucalypts. Rotation ages may vary more as carbon balance and the carbon price of a forest become significant factors in harvesting decisions. Some forests may be managed purely for carbon farming.

Other new uses for forests may emerge such as providing carbon offsets to mitigate landowners' carbon liabilities from other activities, and coppicing crops for bioenergy. The effects of climate change may have regional implications for species selection and forest management.

## 2.7 Land use - crop residue (Biomass)

One Canterbury example is presented below giving summary results of a life cycle analysis.

### 2.7.1 Example of a life cycle assessment for effluent to Combined Heat and Power (CHP) via anaerobic digestion to biogas in Canterbury

Anaerobic digestion (AD) is a mature technology that can yield energy from a wide range of organic waste streams. This biogas can then be used to generate heat and power through a gas motor and genset. Using current anaerobic digestion technology, New Zealand has the potential to produce about 5-6 PJ/annum consumer energy from processing industry waste material and municipal biosolids/animal manure to biogas. This potential is nearly the quivalent of the energy storage in Lake Pukaki, 1679 GWh (note: 1 PJ = 277.8 GWh).

The specific case chosen for this LCA was the anaerobic treatment of dissolved air flotation (DAF) solids from a large sheep and beef slaughtering plant (10,000 stock units per day) in New Zealand. This plant is assumed to produce 5.7 tonnes per day of DAF sludge at 9% total solids (TS).

### Summary

- Potential scale of resource: Nationally 5-6 PJ/annum consumer energy from processing industry waste material and municipal biosolids/animal manure to biogas.
- Energy balance: has an energy return over energy input (EROEI) ratio of 7.2:1
- GHG emissions: >200% reduction in comparison with usual land disposal and grid electricity
- Other environmental benefits: 80% reduction in waste
- Economics: economic at favourable sites (Gross annual operating surplus figures between about 500,000 $/annum and 950,000 $/annum at power prices of 15 c/kWh (depending on local situation) are contrasted with construction costs of about 3-4 million NZ$/plant.)
- Technology status: mature

Uptake could be accelerated by an attempt to identify early implementation sites and by the creation of demonstration facilities.

*Thiele J 2008. High level Life cycle analysis Report for Anaerobic Digestion of DAF sludge from a meat processing plant. Report prepared For Bioenergy Options programme.*

## 2.8 Biofuels – (Biomass)

### 2.8.1 Government policy Feb 2009

**Biofuels** "As you'll know the Government moved swiftly before Christmas last year to repeal the biofuel sales obligation. Despite that, the Government is supportive of the use of biofuels in New Zealand. There are a number of exciting biofuel developments taking place around the country. I've signaled in the past that the government is concerned at the imbalance in the tax treatment between bioethanol and biodiesel.

Bioethanol sales do not incur associated excise tax like the petrol it substitutes, whereas biodiesel and mineral diesel incur road user charges equally. There is no meaningful public policy justification for this distortion. I am particularly concerned that it disadvantages New Zealand biofuel producers whose current focus is biodiesel, in favour of imported ethanol. The Government is undertaking further work in this area, and will look at applying a consistent tax incentive for sustainable biofuels, whether bioethanol or biodiesel. You can expect to hear more from me on this when I open the EECA Biofuels and Electric Cars conference in March." (http://www.beehive.govt.nz/speech/unlocking+new+zealand039s+energy+and+resources+potential)

### 2.8.2 Background

The double imperatives of seemingly enduring higher and increasing oil prices and the need to control and reduce greenhouse gas emissions, especially from transport sources, has resulted in renewed and likely ongoing interest in the development of biofuels, in the form of either bioethanol or biodiesel, as a substitute for traditional transport fuels.

It was beyond the scope of the CRESP Stage 1 study to offer an authoritative analysis of biofuels, the merits and economics of various feedstocks and the merits of bioethanol vis-à-vis biodiesel. The Canterbury region potentially may well be one of the more promising regions within New Zealand for the growing of bioenergy crops.

Canterbury has a range of bioenergy options available that could provide a meaningful contribution to Canterbury's energy future. Canterbury has the potential to fuel itself from renewable resources. This ability is due to a low population density and large areas of land suitable for agriculture and forestry. It is theoretically possible for New Zealand to be self sufficient in terms of liquid fuels by using sustainably managed forests, while having low impact on domestic and export food production. Along with the energy will come ancillary benefits of forests including flood mitigation, improved water quality, erosion control and carbon sequestration. [Source: SCION Next generation biomaterials – Bioenergy Options for New Zealand, November 2007]

| **Type/source** | **2005** | **2030** | **2050** |
|---|---|---|---|
| Forest residues | 18.3 | 43.0 | 36.9 |
| Wood process residues | 8.8 | 11.4 | 23.0 |
| Municipal wood waste | 4.4 | 2.7 | 3.6 |
| Horticultural wood residues | 0.4 | 0.4 | 0.4 |
| Straw | 9.1 | 9.1 | 9.1 |
| Stover | 3.8 | 3.8 | 3.9 |
| Fruit and vegetable culls | 1.5 | 1.5 | 1.6 |
| Municipal biosolids | 0.9 | 1.1 | 1.2 |
| Municipal solid waste, putrescible | 2.8 | 2.9 | 2.9 |
| Farm dairy effluent | 1.5 | 1.5 | 1.6 |
| Farm piggery effluent | 0.1 | 0.1 | 0.1 |
| Farm poultry litter | 0.04 | 0.0 | 0.1 |
| Dairy industry effluent | 0.5 | 0.5 | 0.6 |
| Meat industry effluent | 0.6 | 0.6 | 0.7 |
| Waste oil | 0.2 | 0.2 | 0.2 |
| Tallow | 4.5 | 4.5 | 4.5 |
| ***Total*** | ***57.3*** | ***83.1*** | ***90*** |
| NZ primary energy | 690.0 | 890.0 | 1090.0 |
| NZ consumer energy | 540.0 | 720.0 | 880.0 |
| All biomass, as % of consumer energy | 10.6 | 11.5 | 10.2 |
| All biomass, as % of primary energy | 8.3 | 9.3 | 8.2 |

*Table 2.13: Total possible NZ residual biomass resource for energy production (PJ/year)*

## 2.8.3 The resource

Locally-available biomass resources, in descending order of volume, include woody resources, agricultural plants, and municipal and industrial wastes from various sources. In addition, algal production shows promise as a biomass resource that can be grown using nutrient-rich waste streams.

Canterbury and New Zealand Energy demand, PJ per annum, 2007:

| | |
|---|---|
| Regional heat: | 10.4 (Canterbury), 140.0 (NZ) |
| Electricity: | 17.2, 134.7 |
| Total transport fuel: | 32.8, 244.7 |
| Total energy: | 60.6, 520.3 |

Current energy production from biomass resources is in the order of 45 PJ per annum.

Biomass residues could further contribute another 60 PJ per annum. This contribution could theoretically rise to 90 PJ in 2050, based on increasing residues from increasing volumes of forest harvesting and wood processing. Canterbury currently has 11 PJ per annum of residual biomass, total primary energy, driven by agricultural residues (straws). This has the potential to contribute to 40% of the regional heat demand.

The potential exists to substantially increase the nation's woody resource by using purpose-grown forest crops to meet future energy demands.

Total possible residual biomass resource for energy production is shown in Table 2.13.

New Zealand has a variety of biomass resources suitable for energy production which arise from forestry, agriculture, processing and municipal sources. The contribution that these resources could make to New Zealand's energy demand is outlined below.

Today **forest residue** is the single largest resource, with **agricultural straws and stovers** second. Over time the **wood processing residues** sector (3rd currently) is expected to exceed agricultural residues, on the assumption that increased processing will follow the increased availability of harvested wood. Agricultural residues are assumed to stay relatively static, with little room for major expansion of arable land, although there may be some change in the type of crop being grown.

**Tallow** could potentially make a significant contribution to the production of liquid biofuel, but there is competition for the resource, with the bulk of it already being sold, much of it for export.

**Gas** from municipal waste could also make a contribution of several PJs.

**Effluents and biosolids** come from a variety of sources and are widely dispersed around New Zealand. Collectively they are estimated to be capable of producing 4.5 PJ of energy.

**Woody residues** from all sources are currently over half of the total biomass resource in terms of energy content. By 2050 this could be as high as 65%. A significant driver of the use of biomass resources for the production of energy will be the relative cost of coal, gas and petroleum. Rising costs will increase demand for bio-energy.

## 2.8.4 The goal

The Government has set targets for increased use of renewable energy which will see New Zealand being carbon neutral in:

- electricity by 2025.
- industrial energy by 2030.
- transport fuels by 2040.

In order for New Zealand to be sustainable it must not only be carbon neutral, it must also be economically competitive and have economic growth. Such growth has to occur in an increasingly resource constrained world, therefore it is necessary to:

- meet energy demand from renewables.
- manage land sustainably.
- maintain a robust export sector whose sustainability can be verified and defended.

The generally accepted view of climate change is that it is real, and requires large scale, rapid change to reduce greenhouse gas emissions.

### 2.8.5 The solution

New Zealand can reduce emissions from industrial heat and transport, through efficiency gains and by substituting bioenergy for fossil energy. The use of residual biomass is a logical start point, and a step in the direction of renewables. However, the total amount of energy available from residual biomass is relatively small (around 10%) in comparison with total energy demand. The use of wastes for energy will have large impacts on greenhouse gas emissions because biomass resources tend to produce methane when dumped. If fossil energy is displaced by the use of energy from such waste, there will be a double gain in reduced emissions, along with other environmental benefits. This is particularly relevant to materials such as municipal effluents, biosolids and solid waste. The next logical step is to grow biomass for energy, wherein the limiting resource becomes land. If New Zealand is to achieve bioenergy goals without competing for land with food crops, it is necessary to consider growing medium- to long-rotation forests on marginal lands. These forests would have to be significantly greater in area than the existing planted estate (1.7 million ha). To meet the country's total heat demand, an estate of 700,000 ha would be required. To meet the liquid fuels demand a further 2.5 to 2.8 million ha would be needed. Use of biomass from forests (including purpose grown forests) to produce biofuels has fewer environmental concerns than intensive cropping of arable land because forests:

- do not require intensive fertilisation.
- do not require irrigation.
- do not cause nutrient rich run-off.
- do not compete for high value land used for production of food crops such as corn, wheat and vegetables.

Forests also provide an energy store that can be used when required or processed into other valuable products.

New Zealand has at least 830,000 ha that could be cost effectively used for forestry. Some estimates indicate that there could be as much as 3.0 million ha. A combined energy forest estate of approximately 3.2 million ha could provide most of New Zealand's heat and liquid fuel demand. This is achievable based on the amount of marginal and lower quality grazing land available.

Canterbury has at least 340,000 ha that could be cost effectively used for forestry, and some estimates indicate that there could be more than 570,000 ha. Using this latter forestry area the potential liquid fuel contribution from purpose grown forest (PGF) scenario for Canterbury is 50.9 PJ p.a., plus fuel from residues 1.3 PJ p.a., towards the liquid fuel demand of 38.7 PJ p.a. Canterbury clearly shows significant potential for biofuel production.

### 2.8.6 Key Conclusions

- All available biomass residues combined would meet only 10% +/- of New Zealand's current energy demand. Woody biomass is the bulk of this material.
- Purpose grown crops will be required to meet a larger proportion of New Zealand's energy demand.
- Steep hill country will need to be used for growing this extra biomass to avoid conflict with agricultural production.
- The only viable biomass crop for steep lands is forests, which have additional uses, environmental benefits and can act as a significant energy store.
- Research is required on a range of conversion technologies to improve their economic viability, as well as forest and agricultural crops and algal systems.

## 2.9 Solid Waste/Landfill sites - Energy from Waste

*– Putting Resources to Productive Use – CAE - 2004*

### 2.9.1 Algal Biomass

#### Background

Micro-algae are widely believed to be the precursor of much of the world's fossil oil and gas reserves. Today, algal biomass is seen as a resource for bio-energy production. Algae are potentially far more productive (t/ha) than conventional agricultural crops and can be grown cost-effectively in open pond systems as a byproduct of wastewater treatment. Oxidation ponds, which are the most common form of waste stabilisation pond (WSP) in New Zealand, are ideal for algal biomass production. Conventional WSP, are, however, not optimised for the production of algal biomass, and algae production can be significantly increased by upgrading to High Rate Algal Ponds (HRAP). This process will also enhance the wastewater treatment performance both in terms of absolute pollutant removal and treatment consistency. Conversion products for realising the bioenergy potential of algae biomass include biodiesel, biogas, bioethanol, and bio-oil. Of these conversion options, bio-oil production using super critical water reactors shows considerable promise but requires further research. Super-critical water technology is a possible approach for cost-effective conversion of algae to energy products. Biogas production from anaerobic digestion of algal biomass is a mature and effective technology that is readily available for commercial application. This is a common method of providing fuel on a village-scale for heating and cooking in India. In Germany there are over 4,000 farm-scale biogas plants, many of which digest cultivated crops for electricity generation. Biogas can be purified to natural (methane) gas quality and exported into the national natural gas network, thereby displacing the use of a fossil fuel if economics became favourable.

**Quantities**

At present there is no commercial production of algal biomass in New Zealand. However, existing waste streams offer the following potential:

- Municipal wastewater:

  The potential daily algal biomass yield from each existing WSP in New Zealand was calculated from wastewater fl ow data to give a total of 41 tonnes per day (dry weight). By converting all existing WSP in New Zealand to HRAP the potential daily algal biomass yield could increase to 164 tonnes dry weight/day. If all municipal wastewater was treated in HRAP with addition, the potential daily algal biomass yield could be further increased to 475 tonnes dry weight/day.
- Dairy farm wastewater:

  The daily algae production potential from dairy farm wastewater in NZ using HRAP with $CO_2$ addition would be 1093 tonnes dry weight/day. This is more than double that which could be produced from all municipal wastewater, however, with the production spread over many farms, cost-effective small-scale harvesting and processing technology will be required to realise this potential.
- Pig farm wastewater: There are approximately 250 commercial pig farms in New Zealand, each with an average of 1000 pigs. As all of the daily manure production is treated, the daily algae production potential from piggery wastewater in NZ using HRAP with CO2 addition would be 83 tonnes dry weight/day. The high and concentrated wastewater flows of commercial piggeries compared with those of the largest dairy farms makes piggeries attractive potential sites for algae biomass production.
- Poultry waste: Poultry farming is gaining popularity in New Zealand with approximately 350 laying hen and broiler chicken farms with a total of 24 million chickens. The daily algae production potential from chicken farm manure in NZ using HRAP with $CO_2$ addition would be 136 tonnes dry weight/day. However, as most poultry farms have solid manure collection systems, often with 100% export of the manure, the potential for algae production may be harder to realise that for other agricultural manures.

### 2.9.2 Landfill – Gas reclamation

See section 3.9 Energy from waste.

## 2.10 Gas – new discoveries

See details for Oil in the next section.

### 2.11 Oil - new discoveries

#### 2.11.1: Potential for Development

There is no single forecast for world oil supply. See Figure 2.21.

**Case Study 1: Oil Exploration**

The occurrence of oil and gas in the Canterbury region has been well documented. The Canterbury Basin (Figure 2.22) has a proven petroleum system with large mapped structures.

and, so far, one significant (off-shore) discovery. The first exploration well was drilled to a depth of 661m at Chertsey between 1914 and 1922. A further 2 wells were drilled onshore in 1969, reaching basement rocks at depths of 1650m (JD George-1) and 1159m (Leeston-1). Offshore, Resolution-1 was drilled by BP in 1975. Kowai-1 was drilled in 1978 in North Canterbury by the newly formed state oil company, Petrocorp. Clipper-1 was drilled offshore by BP in 1984. With a total depth of 4742m, this is the deepest well that has been drilled in the Canterbury Basin, and recorded gas and condensate shows. Galleon-1, drilled immediately following Clipper-1 in the North Otago sector of the basin, successfully tested for gas and condensate. Both these discoveries were adjudged by BP to be sub-economic, mainly because of size. Recent exploration has included further seismic surveys both onshore and offshore, and 2 wells were drilled in 2000: Ealing-1 in Mid Canterbury and Arcadia-1 in North Canterbury.

http://www.crownminerals.govt.nz/cms/pdf-library/petroleum-basins-1/canterbury_basin_expl_potential.pdf

A further offshore prospect, Cutter-1, drilled off North Otago starting in October 2006, by Tap Oil on behalf of a joint venture of Australian companies. Figure 5.5 shows the location of the Cutter-1 and Barque-1 prospects in the same permit area. They have also identified a potentially large (Maui-scale) gas and condensate prospect, Barque-1, in deeper water, east of Cutter-1. As yet, there is not a timetable for the exploration of Barque-1. Besides the Tap Group's PEP 38259 offshore North Otago, there are two onshore permits and two other offshore permits in force in the Canterbury Basin, and two areas under application.

http://www.crownminerals.govt.nz/cms/pdf-library/petroleum-basins-1/canterbury_basin_expl_potential.pdf

**Government Policy Feb 2009:**

**Petroleum.** "The Government is interested in acquiring new seismic data to stimulate further exploration for oil and gas. The last round of seismic collection between 2004 and 2007, before the programme was abolished, led to considerable new exploration in New Zealand waters.

Before Christmas I asked my Ministry to free up $3.75 million for some seismic work over this summer. In the year ahead the Government will also be reviewing existing domestic and international petroleum policy, licensing and fiscal regimes. This was signaled in our 2008 election manifesto.

The work will include identification of petroleum, industrial, environmental and economic policies that work well in other jurisdictions and the reasons for their success. The aim of the review will be to recommend measures that ensure NZ continues to have a "fit for purpose" petroleum regime, attractive to explorers and extractors, but also sensitive to environmental

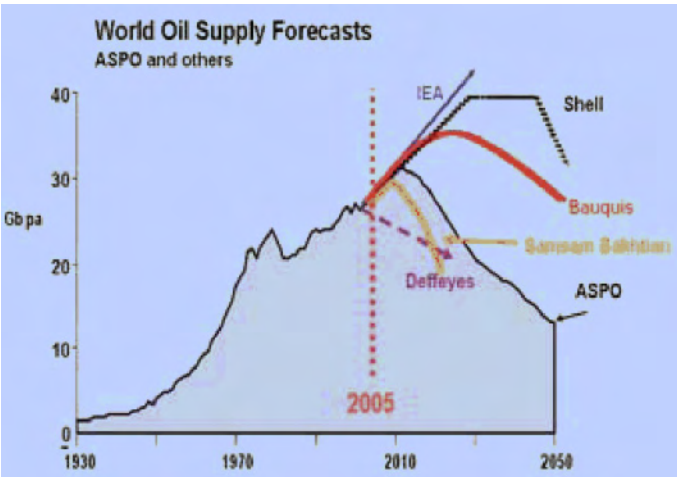


*Figure 2.21: World oil supply forecasts (Source: Australian Association for the* Study of Peak Oil and Gas)

best practice.”

http://www.beehive.govt.nz/speech/unlocking+new+zealando39s+energy+and+resources+potential

## 2.12 Coal

### 2.12.1 New Zealand coal resources

New Zealand has extensive coal resources, mainly in the Waikato and Taranaki regions of the North Island, and the West Coast, Otago and Southland regions of the South Island. The locations of coal resources in New Zealand are shown in Figure 2.23. National in-ground resources of all coals are over 15 billion tonnes, of which 80% are South Island lignites.

Sub-bituminous and bituminous in-ground resources are approximately 3.5 billion tonnes, but recoverable quantities of these coals are uncertain.

http://www.crownminerals.govt.nz/cms/coal/overview/overview#DomesticMarket

### 2.12.2 Canterbury

Over 120 coalmines have operated in Canterbury since 1866, producing a total of about 2 Mt. It is estimated that slightly over half of the total economically recoverable resource remains. There is only one mine currently operating producing around 10,000 tonnes per annum, or roughly 0.25 PJ, for local use and, anecdotally, there appears little interest in further expansion of the industry within the region.

The Canterbury region contains an inconsequential amount of New Zealand’s coal resources.

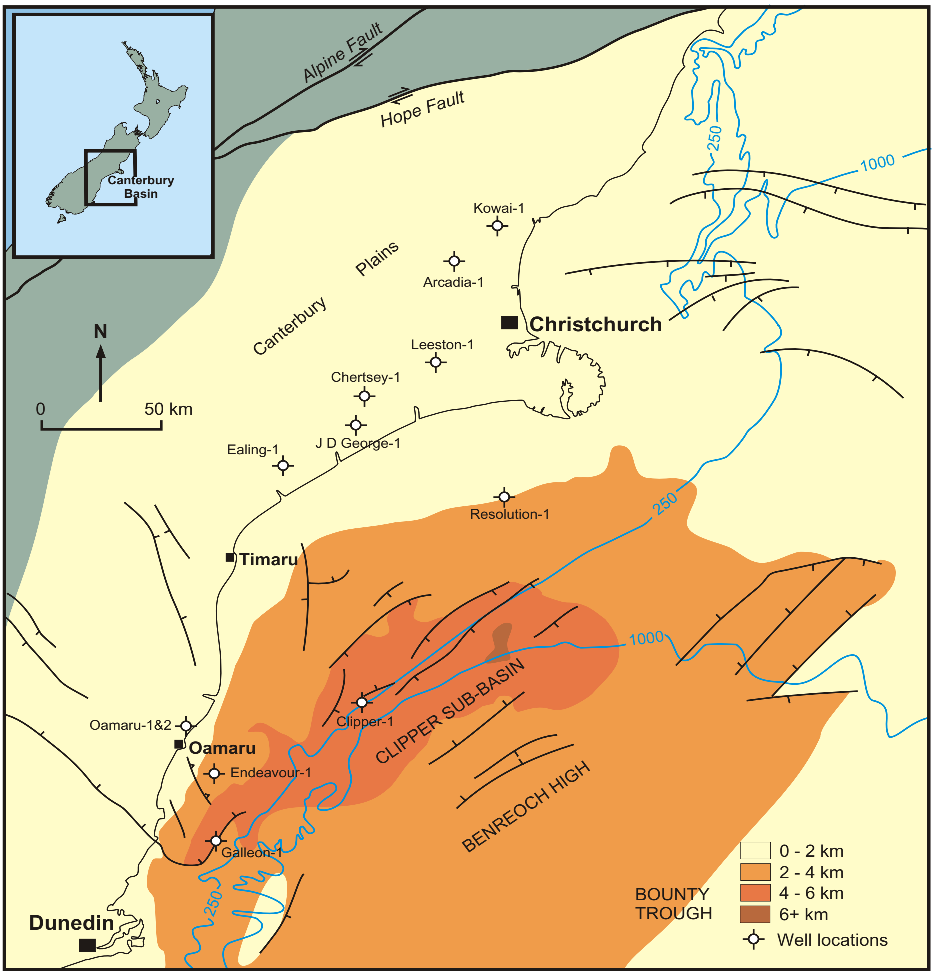


*Figure 2.21: Location of Current Exploration Prospects in the Canterbury Basin*

In Canterbury, over the past 20 years, industrial/commercial consumption has been slowly increasing and substantially counterbalanced by a rapid decline in household consumption where coal fires are now banned. There are currently no coal-fired solid-fuel-burning appliances that would meet the proposed emission limit of 1.5 g/kg. http://209.85.173.132/search?q=cache:g2Bi1j9CjdMJ:www.mfe.govt.nz/publications/air/nes-air-standards-analysis/nes-air-standards.pdf+ecan+coal+burning+fire+ban+2009&hl=en&ct=clnk&cd=4&gl=nz

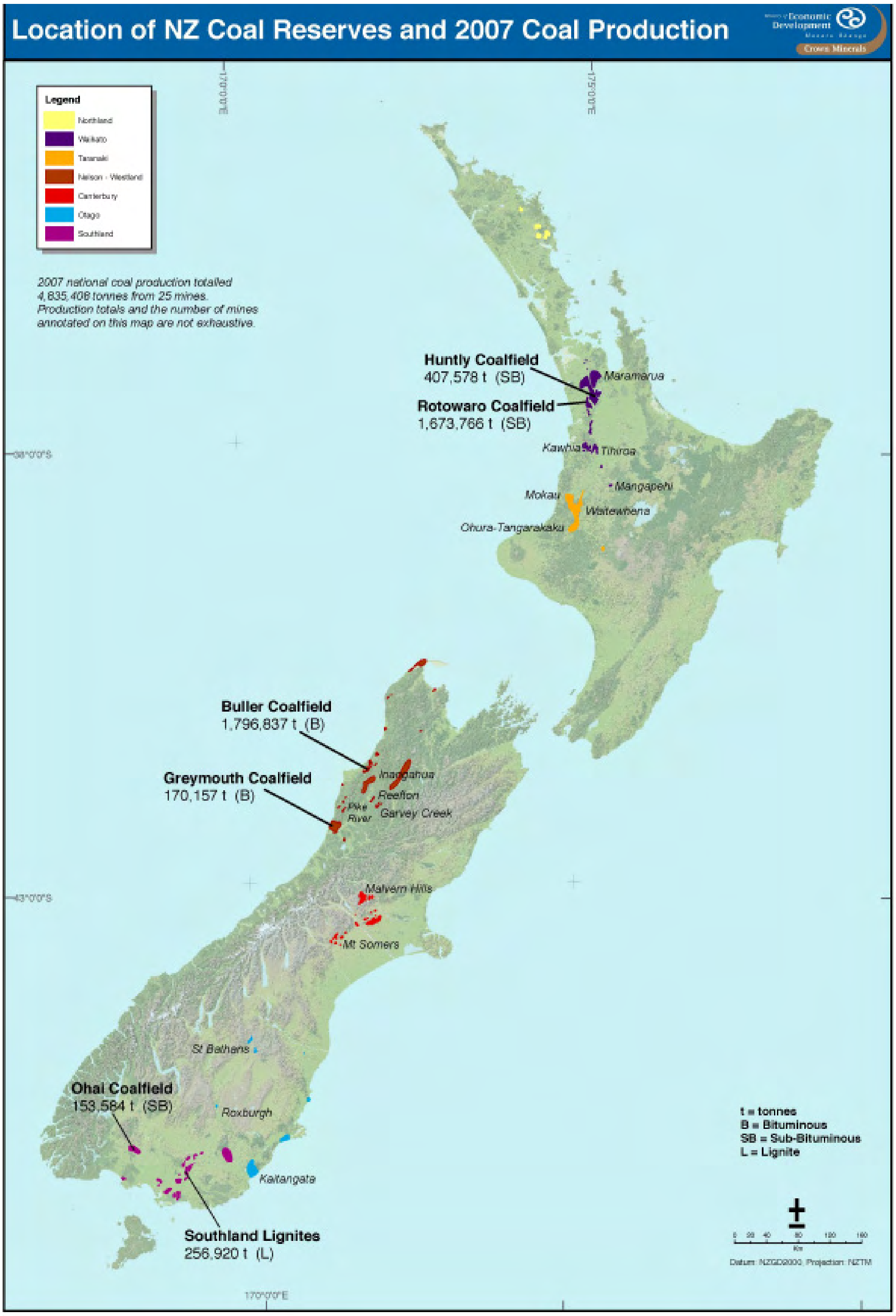


*Figure xx: Coal resources in New Zealand*

# 3 TECHNOLOGIES FOR SUPPLY

This section describes each technology for supply for the potential energy resources that have been identified in Section 2.

Under each technology, as appropriate and, where information is readily available, there is a broad description of the technology, general location requirements, costs & energy units, maturity, risks and Canterbury opportunities.

## 3.1 Hydro Energy

New Zealand has been blessed with many natural resources, not least of which are the major lakes and rivers which have been harnessed to provide hydro power. Large scale developments last century mean that hydro now accounts for between 60 and 70% of total electricity generation. There is also the potential for direct pumping of water for pumped storage or for direct pumping of water for irrigation. In years past industrial power for machines came from water driven systems.

The Pros of hydro electricity

- Clean and relatively abundant source of electricity.
- Already supplies 60% - 70% of our needs.
- Produces no greenhouse gases.
- New Zealand has a wide range of potential sites, large and small.
- Positive public perception of existing hydro plant and renewable energy generally.

The Cons of hydro electricity

- Strong and growing opposition to the environmental impacts of new big hydro schemes.
- Reliant on weather - generation output can vary greatly from year to year.
- Many new schemes would struggle to make electricity at competitive prices.
- Most of the best sites already used or off-limits.
- Low hydro storage capacity in New Zealand.
- Water becoming increasingly competitive for resource consent use.

### 3.1.1 Security of supply

Unlike some of the hydro schemes in countries such as Scandinavia, the USA or Tasmania, which can store several years worth of water inflows, New Zealand's hydro schemes can only store limited amounts. This makes us particularly susceptible to the large year-on-year variations in snow and rainfall that can have a huge impact on the amount of water available to generate electricity in a particular year. This can translate to having 19% more than average in a wet year or, more worryingly, 13% less generation available in a dry year.

### 3.1.2 Hydro generation

The wide range of cost of generation comes about because of the very site specific nature of projects. The necessary project components and their scale (for example diversion and water conveyance works, environmental mitigation works and choice of equipment) depend very much on the location and the intensity of the potential energy. Additionally site specific aspects such as topography and geology drive construction costs while local hydrology determines the energy available from the site. Whereas low head schemes have proportionally large (and slow speed) generating units and relatively low civil works investments, the opposite is the case for high head opportunities where the (small, high speed) machine cost tends to be low, but with a relatively high investment in the diversion works and pipeline. The scheme's proximity to electrical grid, access to site and necessary transportation work (new roads vs. existing) can also affect the project cost substantially, as can the cost of capital (own or borrowed from the market) in the prevailing market conditions. (SKM)

### 3.1.3 The Market for Hydropower Development

Since the cornerstone MWD (1982) report, the electricity industry in New Zealand has undergone significant changes. Different scheme design drivers apply today, affecting the way that the originally conceived schemes would be viewed as investment opportunities, in particular the need for a developer to keep to a minimum the risks and uncertainties associated with environmental effects, ground risk and hydrology.

Though hydropower technology is relatively mature, some technological improvements have been made in civil works, and plant construction and equipment efficiency. For example, the use of a tunnel boring machine (TBM) might nowadays allow a dam to be avoided and for an alternative scheme layout to be considered. Additional infrastructural development such as new roads and transmission/distribution lines may have helped to improve project economics, though conversely, more onerous consenting changes and environmental requirements may make some projects less feasible.

### 3.1. 4 Existing Canterbury hydro generation

The Waitaki River system on the southern boundary of the Canterbury region represents a third (1738 MW) of New Zealand's hydro generation capacity. The chain of 8 hydro stations generates around 7,700 GWh annually, depending mainly on inflows and contributes a major portion of the generation in the South Island, feeding the 220 kV network from the Tekapo B, Ohau and Waitaki Valley generation stations. The oldest of the dams (Waitaki) is illustrated in Figure 3.1.

Elsewhere in the region (excluding South Canterbury), the region's main generation is the Coleridge Power Station. This is a 45MW capacity hydro generator that enters the core grid at the Islington GXP.

Embedded generation plant contributes a very small amount of generation to the region:

- approximately 3 GWh (predominantly diesel and gas) in the Orion network
- a 7 MW hydro station embedded in South Canterbury at Opuha
- Montalto (1.8 MW) and Highbank (28 MW) hydro stations in the Electricity Ashburton network.

In Section 2.1, Table 2.2 summarises these existing hydro schemes.

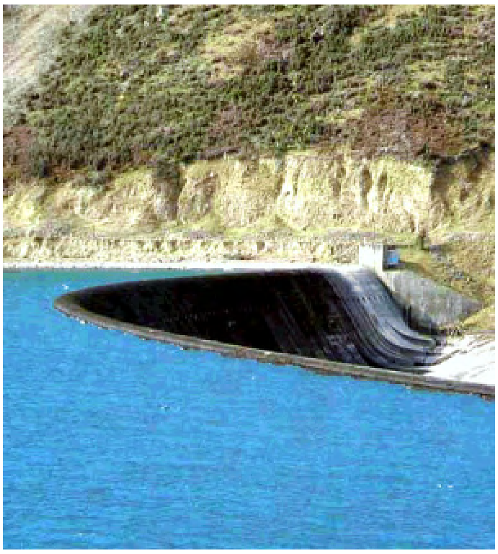

*Figure 3.1: Waitaki Dam (Mike O'Connell)*

### 3.1.5 Opuha Dam example

The Opuha Dam (Figure 3.2) was commissioned in 1999 after a protracted development stage including many years to secure agreement and resource consents, and a breach of the dam during construction. While initial uptake of irrigation was relatively slow, the scheme is now fully subscribed and shares have sold at a premium of over 10 times their original cost. There is significant economic prosperity mainly resulting from the impact of irrigation:

| | |
|---|---|
| Output ($/yr) | +$124,000,000 |
| Value Added ($/yr) | +$41,000,000 |
| Household Income ($/yr) | +$20,000,000 |
| Employment (FTE's) | +480 FTE's |

*Source: The Opuha Dam: An ex-post study of its impacts on the local economy & community. Harris Consulting, May 2006.*

*Figure 3.2: The Opuha Dam*

### 3.1.6 Capital cost estimates for Canterbury small hydro schemes

Capital cost estimates for potential Canterbury small hydro schemes, indexed to June 2006 are shown in Table 3.1.

### 3.1.7 Other Possible Hydropower Options

In addition to the potential for new conventional hydro installations (developing head and diverting flow to generate electrical power by conventional water turbines), other means of increasing the contribution of hydropower include:

- **Rehabilitation and/or Uprating of Existing Plant**

  Modernisation and refurbishment of the water turbines and generators at existing hydropower schemes can typically realise an increase in output of 10 to 20% and/or (depending on their relative value in the power market) additional energy across the operating envelope of typically 2 or 3%.

- **Alternative Technologies**

1 There are some experimental technologies that in the future may become viable to harness hydro potential. Helical turbines for example (for 'ultra low head' applications) are a reaction crossflow machine, developed between 1993 and1995 at Northeastern University in Massachusetts. The turbine operates in the streamflow and extracts energy from the stream velocity. Steep reaches in rivers with water velocities >1.0 m/s can provide potential sites for machines in series.

2 Other new technologies evolving, intended to reduce the complexities and capital costs of small hydro schemes, and for 'modular' applications, include siphon type turbines, variable speed and PMG generators and plastic pipelines. For the very small schemes, waterwheels with gearboxes or belt-drives can still have a place.

3 Since 2002 water turbine drives for irrigation pumps which cost virtually nothing to run, have been installed on Mid-Canterbury irrigation schemes. On the first scheme Graeme Martin (Lincoln University) worked with Robert and Leighton Jones of Carew on the design, manufacture and installation of a water turbine on one of the distribution races in the Mayfield/Hinds irrigation scheme. The turbine drives an irrigation pump supplying the spray irrigation scheme which incorporates a Briggs Rotorainer. Previously the Jones used a diesel engine, pump and big gun irrigator with an annual fuel cost of $10,000 - $20,000. Now with the water turbine scheme, operating costs are virtually zero. The turbine was publicly introduced at an Irrigation Field Day on the Jones' property on 17 April 2002 with around 100 interested participants attending. Graeme Martin supplied the following technical details: Approximately 1.2 $m^3/s$ of water is diverted out of the main irrigation race, flows along an elevated channel, falls 4.5m vertically through a penstock into the turbine and flows from this along the tailrace to rejoin the main race three drop structures downstream from where it was extracted. The turbine drives the centrifugal pump through a speed-up drive and is delivering about 40 litres/sec at 560 kPa into the underground mainline. Further installations on the Mid-Canterbury irrigation schemes have been built saving farmers many thousands of dollars in either diesel or electricity pumping costs.

4 Farmers on the Waimakariri River irrigation scheme in North Canterbury are investigating sharing water with a small-scale hydropower generation unit. The district's electricity lines company MainPower wants to build the station near the intake to the irrigation scheme, at Brown's Rock, a few kilometres downstream from the bridge on SH1. The two parties are analysing the economics and implications of the project but, in a submission to the Ministry of Economic Development, Waimakariri Irrigation Ltd (WIL) has already endorsed MainPower having the right to build generation in the area. A plant capable of producing 4-8 megawatts is planned. This would be enough to supply about one-third of the needs of the district's major town, Rangiora (December, 2006).

5 Natural Systems Ltd (NSL) established by Brian Tolley, Ian Bywater and joined by Ken Hulls has an objective to exploit selected renewable generation technologies including HydroVenturi technology via licence. HydroVenturi Ltd is a spin off company from the Physics and Mechanical Engineering Departments at Imperial College in London – 2005. The technology takes the

| River/Site | Capacity (MW) | Head (m) | Energy (GWh/yr) at 50% PF | Capital Cost (NZ$M) Indexed to June 2006 | NZ$/kW Indexed to June 2006 |
|---|---|---|---|---|---|
| **North Canterbury** | | | | | |
| Boyle River | 3.2 | 55 | 14 | 21.0 | 6,569 |
| Kakapo Brook | 5 | 180 | 22 | 21.8 | 4,362 |
| Lake Sumner outlet (b) | 8 | 30 | 35 | 49.3 | 6,163 |
| Hurunui River North Branch1 | 17.6 | 46 | 77 | 92.5 | 5,258 |
| Hurunui River at Lowry Peaks | 35 | 45 | 153 | 189.6 | 5,418 |
| Ashley Gorge dam | 7.7 | 37 | 34 | 52.0 | 6,749 |
| Ashley River | 5 | 30 | 22 | 30.5 | 6,100 |
| **Central Canterbury** | | | | | |
| Waimakariri Gorge | 15.7 | 40 | 69 | 76.4 | 4,866 |
| Rakaia Canal Schemes | 34.2 | 33 | 150 | 198.6 | 5,806 |
| Poulter River Dam to 488m | 15.4 | 30 | 67 | 74.7 | 4,847 |
| Broken River | 8.7 | 134 | 38 | 68.9 | 7,917 |
| **South Canterbury** | | | | | |
| Jacks Stream | 4 | 360 | 18 | 24.5 | 6,115 |
| Bush Stream | 30 | 400 | 131 | 198.7 | 6,625 |
| Boundary Stream | 2.4 | 290 | 11 | 17.7 | 7,388 |
| South Branch Ashburton River & Rangitata River: | | | 0 | | |
| Lambie Stream Scheme (ii) | 52 | 244 | 228 | 371.0 | 7,134 |
| Rangitata River at Gorge | 40 | 35 | 175 | 305.7 | 7,644 |
| Rangitata River, Diversion Race | 32 | 54 | 140 | 244.6 | 7,644 |
| Lake Stream and Rakaia River | 22.5 | 120 | 99 | 206.4 | 9,173 |
| Opuha River | 9.5 | 85 | 42 | 92.0 | 9,682 |
| **Waitaki** | | | | | |
| Lower Waitaki Irrigation - McPhersons Rd 2 | 2.33 | 20 | 10 | 13.2 | 5,652 |
| Waiareka-Kakanui Irrigation No 1 | 9.17 | 50 | 40 | 46.4 | 5,058 |
| Maerewhenua River | 2.15 | 60 | 9 | 21.5 | 9,995 |
| Ahuriri-Avon Burn No's 1 & 2 | 6.2 | 36.5 | 27 | 34.7 | 5,590 |
| Ahuriri River-Lake Ohau | 14.6 | 82 | 64 | 97.1 | 6,648 |
| Hopkins River | 8.5 | 30 | 37 | 50.2 | 5,911 |
| Huxley River | 4.1 | 55 | 18 | 30.8 | 7,512 |
| Temple Stream | 3 | 60 | 13 | 18.0 | 6,000 |

*Table 3.1: Capital cost estimates for Canterbury small hydro schemes (SKM, 2006)*

Venturi effect (Bernoulli's Theorem) applied to water flows and optimally engineers this to provide pressurized air flows for operation of air driven turbo generators. Potential NZ Market:

- Opportunities within existing Hydro and Irrigation Infrastructure, est. 100MW
- Potential within remaining Hydro. MED estimate 2500MW. Not all suitable for low head
- Other low head Hydro. No estimate
- The technology was developed with tidal energy in mind. Major advantage in first 'perfecting' the technology in low head hydro as proving ground for tidal.

6 In total the contribution of 'micro' hydro is likely to be significant. However the potential has never been identified, for obvious reasons – including: dispersed nature of the resource, technical and regulatory complexities, proportionally high development overheads, and landowner issues.

7 Additional potential hydro sites can be identified through the use of modern GIS techniques using updated geographical information. GIS techniques can be used to isolate reaches of rivers with reasonable slopes and to estimate flows to determine the theoretical energy potential of the site. This will be especially relevant in determining small, mini and micro hydro sites where this type of screening approach would potentially be very useful.

### 3.1.8. Meridian and South Canterbury Irrigation Trust proposal for South Canterbury

Meridian Energy and the South Canterbury Irrigation Trust (a collaboration between Timaru, Waimate, and Mackenzie District Councils) plan a major sustainable irrigation initiative for South Canterbury. The Hunter Downs Irrigation scheme initiative with Meridian Energy has the potential to transform the South Canterbury district, from Waihao to as far north to Otipua, and which could drive regional economic growth for many years to come.

There are synergies between hydro and irrigation. The Hunter Downs Irrigation scheme would potentially irrigate up to 40,000 hectares out of a total command area of 60,000 hectares. Water would be sourced from the lower Waitaki River and transported through a system of pumping stations, pipes and canals.

What is not clear is the potential for recovery of energy used in pumping, as the water flows down to the various farm properties.

### 3.1.9 Hydro Energy Risks – impacts, visual, audio, pollution, environmental issues

**Impacts:**

Reduction in river water flow rates ($m^3/s$) for

- irrigation & water supplies; dry land farming is a major risk for farming and the land becomes much more valuable with available water for irrigation, this increased value may be more than the value of the water for energy. (competition)
- recreation , including swimming, boating, rafting, fishing, (low flows)
- plants, animals, birds living in and around river beds (un-natural flows)
- flushing of river beds, sediment transport to the coast (smaller moderate flood flows)

Any barrier to the free passage of water, sediment and bed load–

- some recreation activities are blocked
- fish passes may be required
- sediment and bed load is likely to fill the water storage area (many years) limiting the life of the system
- sediment and bed load does not continue to coast or natural lake.
- coastal erosion may be accelerated
- bridge clearances up-steam of a barrier may be reduced and endanger the structure
- river bed levels may drop below the barrier, and the banks become eroded
- bridge piles/abutments downstream may be eroded and require re-building
- a by-pass to allow sediment to effectively pass through or around the barrier may be required (Tunnels just for this purpose are being built on some recent constructions to reduce the impact of barrier dams)

- drowning of land areas – this land may have potential for high value crops for the micro climate, structures and access may need replacement, remaining farming units may be require reorganisation, clearing of land vegetation may be necessary, release of $CO_2$ etc may be an issue, mudflats on an exposed lake bed may cause a dust nuisance with variable lake levels, lack of stability of steep ground may require stabilising, new shore beaches may need to be created, major flood events need to safely pass the barrier.

**Visual:**

- new structures and development of access result in a change in the scenery,
- water storage creates a lake,
- some of the engineering works may be placed underground.
- Major flood waters on a spillway create an interesting spectacle.
- Transmission lines can interfere with views of scenery.

**Audio:**

- the sound from the spinning turbine is generally contained within the structures.

**Pollution:**

- The creation of storage lakes can increase wind-blown dust issues.
- The process of taking energy out of the water (slightly cooling it) is considered by most people to be a clean process and the energy to be classified as renewable.

## 3.2 Marine generation technology

### 3.2.1 Wave & Tidal Power Devices

Many wave device designs are under development and there is, as yet, no convergence on a common design. Five generic designs are maturing. Two of these – attenuator devices (like the well-known Pelamis device) and point absorber devices (like the WET-NZ device) have been evaluated for their potential use at six New Zealand sites. Whilst there are many different tidal device designs, the fastest to mature is probably the horizontal axis turbine – like a submarine wind turbine. Tidal rise and fall technologies are simple – barrages or impoundments – but there are very few sites where such technologies could be deployed in New Zealand. Examples of wave devices and a horizontal axis device are shown in Figures 3.3 to 3.7.

### 3.2.2 Performance characteristics of a wave energy converter

It is essential to understand the performance characteristics of any wave energy converter (WEC), in order to characterize the power produced by the device. The following is a layperson's summary.

There are a variety of different wave energy conversion methods and different device designs under development. These come in a range of sizes and generation capacities. Performance characteristics are generally more difficult to characterize than for other forms of renewable energy, because the power produced by a wave energy converter is generally dependent on multiple parameters.

Raw wave power - the energy flux within a wave field - is proportional to the wave period (T) and the square of the wave height ($H_{sig}^2$). The significant wave height ($H_{sig}$), which is the statistical average of the highest 1/3rd of the incident waves, is used in place of average wave height.

Similarly, the power captured by the action and operation of a device is also dependent on both the wave height and the period. In an ideal world technology developers would publish accurate performance characteristics that had been thoroughly calibrated through

*Figure 3.3: The Pelamis P750 Prototype in Leith, Edinburgh (workers show scale)*

*Figure 3.4: 40 kW PowerBuoy Ready for Deployment*

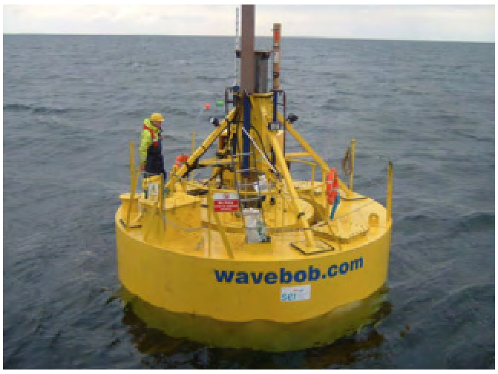


*Figure 3.5: 1/4-scale WaveBob Prototype in Galway Bay, Ireland*

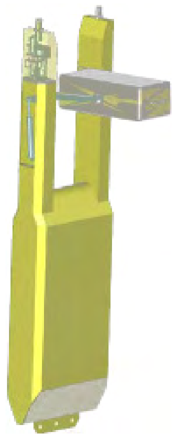

*Figure 3.6: WET-NZ's Point Absorber Wave Energy Converter*

testing and operational experience. In the real world most WEC developments are not sufficiently advanced to derive these performance characteristics. In any event, most WEC developers are either unable or unwilling to release this information.

### 3.2.3 Selection and grouping of device type

Selection of device type would be critical in the less productive east coast locations (Canterbury) but device survival (and capacity factor) are likely to be bigger issues at the more

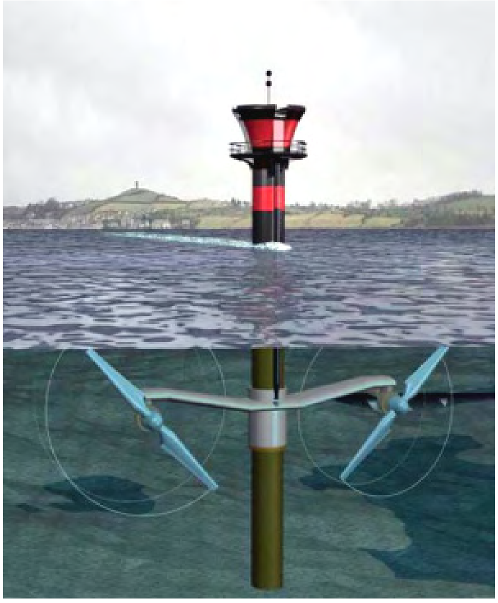

*Figure 3.7: Artist's Impression of SeaFlow Device*

energetic locations.

The density of packing of wave energy devices in an array is an area of active research and the only current array in the world is three CETO II devices moored outside Fremantle Harbour. Carnegie Corporation claims that they will ultimately achieve 8 MW/km$^2$ for the CETO II device (very low rated capacity). For wave energy devices modelled the density packing ranged from 12.5 to 25 devices/km$^2$ and the generation density from 11.25 to 18.75 MW/km$^2$.

### 3.2.4 Costs

Ultimately the widespread deployment of marine energy technologies will depend on developers being successful in reducing capital costs and operating costs, so that the unit cost of electricity from a marine energy converter is competitive with lower cost forms of energy, such as gas-fired Combined-Cycle Gas Turbines, geothermal and wind power. Otherwise, marine energy will have but niche application.

Marine power generation costs are expected to drop considerably over the next decade. It is expected that the cost curve will be similar to the wind power generation. However, it must be noted some cost components, especially Operation & Maintenance, can only be estimated with high uncertainty at this stage. (SKM 2006)

### 3.2.5 Development of marine energy

The development of marine energy depends not only upon the ingenuity and capabilities of device developers but also upon an array of external factors, including national targets for uptake of renewables (including marine), government assistance, funding mechanisms, industry developments and investor confidence. The New Zealand Government has begun to support marine energy but specific support for new renewables is limited. Policy instruments, such as renewables obligations, feedin tariffs and regulatory assistance, have stimulated marine energy device developments and deployments in the United Kingdom, Portugal, Denmark, Canada and the United States.

The international and national growth of wind energy has been reviewed as a template for the potential growth of marine energy. Current development of marine energy is lagging behind forecasts of only 7 – 8 years ago. However, developers with maturing technologies are beginning to permit multiple sites so very rapid growth may occur, as new technologies mature to commercial status. Two domestic marine energy developers have announced aggressive development plans, which are at odds with the observed development of the wind industry here. New Zealand can expect to see the first demonstration projects in the next 3 – 5 years and the first commercial deployment in 3 – 7 years. Canterbury sites may well be some years longer.

To illustrate the attainable power potential, a simple case study based upon resource potential and assuming Pelamis deployed technology may be considered to demonstrate the wave power extraction viability. Operating in the 18 kW/m wave climate environment, each unit would produce around 130 kW (significant wave height 1.8 m and wave period of 8 seconds), and spacing the units 150 m apart, a farm array of 14 devices would occupy a foot print of 2100 m by 150 m. Assuming the developers quoted load factor of 40%, the annual energy production per unit would be 455 MWh, which approximates to 6.37 GWh per farm. At a 40% load factor, this equates to an average output of about 2 MW. (SKM 2006)

### 3.2.6 Ocean Thermal Energy

Ocean temperature gradients can be exploited by means of heat engines. The technology is referred to as Ocean Thermal Energy Conversion (OTEC). Cold water from deep beneath the surface is pumped up and the temperature difference to warm surface water used to drive a heat engine. Technically achievable efficiencies are around 3%. The technology is only viable if temperature differences are 20°C or more, limiting its scope to the tropical climate zones, approximately +/- 20° of the equator. OTEC is therefore not an option for Canterbury.

### 3.2.7 Osmotic Power

When freshwater meets saltwater, for example where a river flows out into the sea, enormous quantities of energy are released. This energy can be utilised to generate power through the natural phenomenon of osmosis.

Osmotic power is based on the natural phenomenon of osmosis, defined as ‘the transport of water through a semi-permeable membrane’. This is how plants can absorb moisture through their leaves and retain it.

In 2008, Statkraft constructed the world’s first prototype osmotic power plant at Tofte, southwest of Oslo.

Energy created by osmosis has very little impact on the environment. Another advantage is that osmotic energy is renewable, since the process does not “consume” the salt. Osmotic-produced power is much more expensive than for example fossil fuels. There are also engineering problems to be overcome.

### 3.2.8 Wave Power Device Risks – impacts, visual, audio, pollution, environmental issues

**Impacts:**

- the location and the large area of a grouping could be in conflict with shipping and fishing
- underwater sea bed cable needs protection from dragging anchors

**Visual:**

- typically not seen from the coast

**Audio, pollution, environmental issues:**

Not considered significant

## 3.3 Geothermal Technologies

Geothermal systems can be divided into two main groups – conventional and engineered. It is important to note that direct heat use can be a more efficient use of the geothermal resource, given that huge amounts of heat are used in industrial processes. The use of direct heat is referred to later in discussion of biomass.

1. **Conventional geothermal systems** that contain naturally occurring hot water in porous and permeable rocks have been discussed in Section 2.
2. **Enhanced geothermal systems (EGS)** is where a heat source is present but lacks a reservoir. This has to be artificially engineered. It is also referred to as hot rocks or hot fractured rocks (HFR). HFR is a type of geothermal power production that uses the very high temperatures (of about 200 degrees Celsius) that can be found in rocks a few kilometres below ground. Electricity is generated by pumping high pressure water down a borehole (injection well) into the heat zone. The water travels through fractures in the rock, capturing the heat of the rock until it is forced out of a second borehole as very hot water, which is converted into electricity using either a steam turbine or a binary power plant system. All of the water, now cooler, is injected back into the ground to heat up again in a closed loop (see Figure 3.8). HFR technologies, like hydrothermal geothermal, are expected to be baseload resources which produce power 24 hours a day like a fossil plant.

### 3.3.1 Examples:

1 **Cooper Basin, in South Australia**, has been shown to contain more than 400,000 petajoules of high-grade thermal energy.

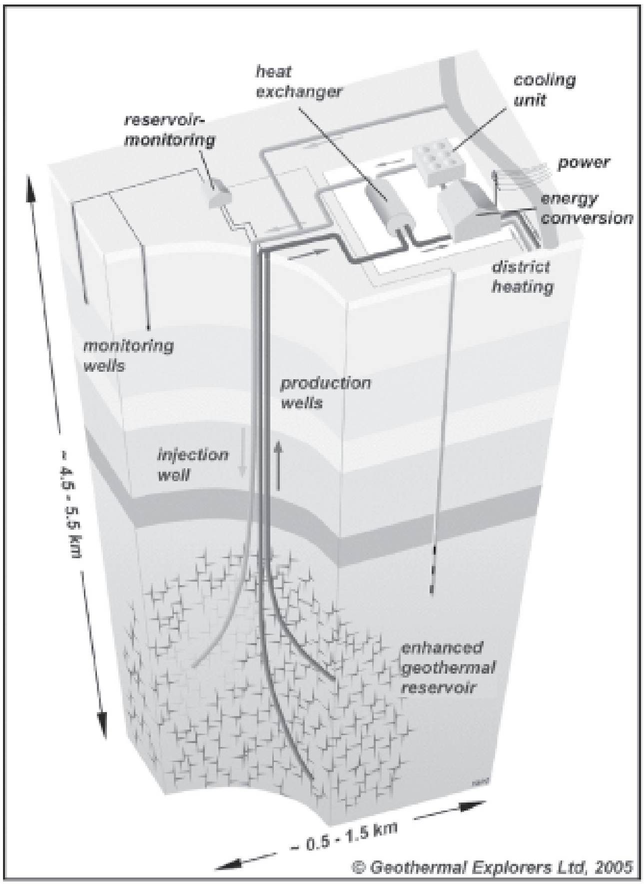


*Fig 3.8: Illustration of an EGS system with one injection well and two production wells. The monitoring wells are for micro-seismic sensors. Figure courtesy of M. Häring of Geothermal Explorers Ltd.*

Project studies, including long-term production modelling, have shown that these resources have the potential to support generating capacity of more than 10,000 MW. Following proof of concept, Geodynamics should produce its first megawatts of geothermal power by the end of March, 2009.

2 **Perth Basin.** Harnessing geothermal energy in the Perth Basin, Western Australia, is one step closer with the announcement of the preferred applicants for geothermal exploration. Most of the applicants, who will be granted permission after completing Native Title negotiations, are expected to use the geothermal energy to generate electricity for the State's power needs. The expected expenditure for geothermal exploration for the 36 permits in the Perth Basin is more than $560million in the next six years. This industry has the potential to provide clean energy to the State's electricity network and offer innovative solutions for companies to meet their own power requirements.

3 **USA Geothermal Resources** Geothermal energy recently began to draw serious investor attention when the Massachusetts Institute of Technology (MIT) released *The Future of Geothermal*, a comprehensive study on geothermal resources in North America. The study said if 40% of the heat under the US could be tapped, it would meet demand 56,000 times over. It said an investment of $800 million to $1 billion could produce more than 100 gigawatts of electricity by 2050, equalling the combined output of all nuclear power plants in the US.

### 3.3.2 New Technologies

1. There is new turbine technology that can produce power from resources as low as 74 degrees C. In July 2007, a 200-kilowatt generator in Alaska started making electricity from water at 74 degrees Celsius, the lowest temperature on record.
2. Geothermal energy can be harnessed as a co-product of oil drilling. Many existing oil wells bring up sizable quantities of water at temperatures sufficient to run small turbines. While the resource at any one oil well is likely to be small, aggregating all the wells in a large oil field could produce significant power at low cost.
3. **Kalina cycle technology** The Kalina cycle engine, which is at least 10 percent more efficient than the other heat engines, is simple in design and can use readily available, off-the-shelf components. This new technology is similar to the Rankine cycle except that it heats two fluids, such as ammonia and water, instead of one. Instead of being discarded as waste at the turbine exhaust, the dual component vapor (70% ammonia, 30% water) enters a distillation subsystem. This subsystem creates three additional mixtures. One is a 40/60 mixture, which can be completely condensed against normal cooling sources. After condensing, it is pumped to a higher pressure, where it is mixed with a rich vapour produced during the distillation process. This recreates the 70/30 working fluid. The elevated pressure completely condenses the working fluid and returns it to the boiler to complete the cycle. The mixture's composition varies throughout the cycle. The advantages of this process include variable temperature boiling and condensing, and a high level of recuperation.

   Kalina cycle technology has the potential to be a competitive technology in the geothermal area. Cost competitiveness with modular ORC technology may be difficult to achieve until a global market develops for Kalin cycle technology. Initial applications may be on low temperature resources where scalability is important, such as at the Geodynamics Hot Dry Rock programme at the Cooper Basin in Australia. The technology is now being used in geothermal power plants.

### 3.3.3 Commercial Viability

From an Australian study HFR geothermal energy can be produced more cheaply than all other electricity generation options if the cost of carbon emissions is factored in (Figure 3.9).

### 3.3.3 Summary for Canterbury

1. There is a zone of hot springs associated with the alpine fault, some of which are used for heating swimming pools.
2. There are no known resources available in Canterbury for conventional geothermal power generation.
3. Enhanced geothermal system technology is not promising in Canterbury as it does not appear to have a high crustal thermal

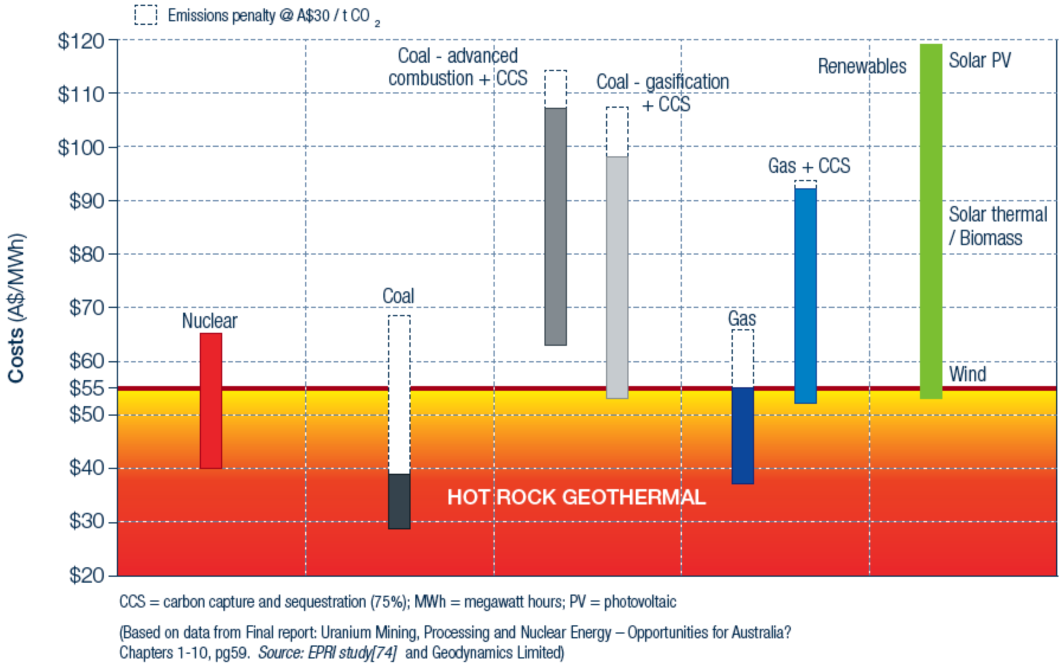


*Figure 3.9: Australia's Power Options*

gradient and its volcanic nature poses potential difficulties creating the required underground fractured rock heat exchangers. However, this may need further study.

4. Drilling is the single most costly item for EGSs. Development of hydrothermal drilling techniques could significantly reduce drilling costs. If this development succeeds, geothermal power will be practical virtually anywhere.

### 3.3.5 EGS System Risks – impacts, visual, audio, pollution, environmental issues

**Impacts:**

- The process of constructing deep holes as for oil well drilling could be a noise disturbance locally.

**Visual:**

- Transmission lines.
- Large buildings/ equipment /piping, and cooling towers with the release of steam.

**Audio:**

- unknown?

**Pollution, environmental issues:**

- Potential heated water if local river used for cooling.
- Concern that there may be pollution in some form with the deep aquifers.

## 3.4 Wind

### 3.4.1 Wind power generation

The generation costs from large scale wind farms depends significantly on the average wind speed. Costs can vary significantly between projects, depending on complexity of the terrain and resulting higher costs for access roads or long distance to the grid with high investment needed for the grid connection.

In 2006 the electricity prices required average wind speeds of around 8 m/s for projects to be economically viable. Increases in electricity prices have made areas with lower wind speeds attractive for developers also. Wind turbine prices have dropped considerably over the last decade due to a large increase in manufacturing rates/capacities and technology enhancement.

However, this trend did not continue. From the year 2005 a general increase in turbine prices was partly due to higher steel prices. Furthermore, some manufacturers were forced to increase prices to avoid financial losses and make the business more profitable. Profit

*Figure 3.10: Southbridge, 100 kW*

*Figure 3.11: Gebbies Pass, 500 kW*

margins have been very small in the past due to a very competitive market.

The successful implementation of wind energy in Europe during the past decade has led to an upcoming market for second hand wind turbines. Repowering (replacing smaller with larger wind turbines) of wind farms after 5 to 15 years of operation releases a large number of second hand turbines into the market. These wind turbines in the range of 30 to 1000 kW

*Figure 3.12: Typical wind turbine for electricity generation*

often represent state of-the-art technology enabling 10 to 15 years of remaining life expectancy and are available at relative low initial costs (1,000 $/kW are targeted by local developer Energy3 (Energy3, 2006)). However, when re-erecting used turbines certain precautions have to be taken to ensure high availability of operation. An overhaul of major turbine components might be necessary. Furthermore, demand for second hand turbines is increasing world-wide with turbine prices expected to be going up at the same time.

### 3.4.2 Potential Electricity Generation from Wind

Wind power generation has become a significant contributor to electricity generation in many regions around the world (especially Europe and US). There is currently 60,000 MW of wind power installed worldwide. Germany alone has almost 18,000 installed wind turbines with a total capacity of around 18,500 MW. The development of wind power in New Zealand had been delayed for many years because of very low electricity prices, which made it uneconomic to install wind turbines. Rising electricity prices during the last few years have changed this, and wind farms are now competitive with other forms of electricity generation. New Zealand's total installed wind power capacity of 321 MW is still very low when compared internationally.

There are currently no wind farms in the Canterbury region, but two single wind turbines as illustrated in Figures 3.10 and 3.11. A typical wind turbine for electricity generation is shown in Figure 3.12.

MainPower is investigating two potential wind farm sites at Doctors Hill and Mt Cass in North Canterbury. (SKM - 2006)

**Mount Cass Wind Farm.** On 23 November 2007, MainPower lodged an application for resource consent to build a wind farm on Mt Cass, about six kilometres east of Waipara in North Canterbury. MainPower has a vision of energy self sufficiency for their region. Despite the fact their region has a lot of renewable energy resources there is no local generation – more than a million dollars leaves there every week to other generators.

Depending on the turbines chosen, the Mt Cass wind farm could generate between 41 MegaWatts of power - enough energy for 11,000 homes, and up to 69 MegaWatts of power – enough energy for up to 24,000 homes. There are 4,000 homes in the Hurunui District and 14,000 in the neighbouring Waimakariri District. It could be connected to the Waipara 66 kV bus without any restrictions with all transmission assets in service. Any additional generation injection slightly above 60 MW would require automatic controls to limit generation following some outages, to prevent circuits from overloading.

This proposal has been declined by the Hurinui District Council-appointed comissioners (April 2009).

### 3.4.3 What does wind energy cost?

Estimates of the cost of wind-generated electricity vary from $60 to $120 per megawattt hour (MWh). The reason for this wide range in estimates is that many of the factors that affect costs are site specific - such as wind speeds, capital and construction costs, as well as the cost of connecting the wind farm to transmission lines. In New Zealand, wind farms do not receive subsidies. For this reason, wind farm developers will only build a wind farm if it can produce electricity at a cost that is competitive with other forms of generation.

### 3.4.4 Wind increasingly competitive

The combined effects of rising fossil fuel prices and the introduction of a cost on greenhouse gas emissions will push the cost of thermal generation above wind energy. Many of the costs associated with thermal generation are uncertain, but trends suggest they are likely to rise. The rising price of natural gas has been an important driver of increasing electricity prices. This trend is expected to continue, and could push electricity prices up another $15 to $25/MWh.

New Zealand's emissions trading scheme will require generators to meet their emission costs from 2010. Analysis by NZIER shows that a cost on carbon emissions of $NZ33.32 would increase the cost of coal generated electricity by $33.32/MWh and gas generated electricity by $16.66/MWh.

### 3.4.5 Future costs of wind generation

The fuel for wind farms - the wind - is free. This means the future cost of wind energy will not be affected by increasing fossil fuel prices or the cost of greenhouse gas emissions. There are other costs to integrating wind energy into the electricity system, but these costs are estimated to be less than the costs associated with continuing to rely on thermal generation.

A professor of electrical energy systems at Imperial College in the UK, commissioned by Meridian Energy, identified that costs associated with greater use of wind in New Zealand included additional costs for system reserves (instantaneous, frequency-keeping and scheduling reserves) and generation capacity (as wind has limited ability to provide generation capacity at peak demand). For integrating 2000 MW of installed generating capacity by 2020, the additional cost would be between $2.06 and $2.76/MWh of wind energy - an amount significantly less than the effect of the cost of carbon on gas and coal generated electricity. The study noted that the cost of integrating wind into the New Zealand electricity system is many times lower than experienced in Europe, primarily because of New Zealand's excellent wind resource and significant hydro generation.

### 3.4.6 Domestic sized wind turbine systems

Wind turbines use the wind to turn a propeller that generates electricity in an alternator. They are viable as small-scale generators that can provide electricity to a building or property separately from the mains supply. The main requirement is that the wind generator location is exposed to sufficient intensity and duration of wind. They are more viable in remote locations as they can produce noise and are may be regarded as unsightly. Quoted figures for the wind generators' efficiency at converting energy to electricity is about 45%. A resource and building consent will be required for the erection of a wind turbine. Typical domestic wind generators can range in capacity from 0.3 kW to 5 kW.

#### Electricity supply connection

Electrical power from the wind generator system can be available all times of the day, but the output levels can be variable as wind speed changes. Typically the output AC is converted by a rectifier to DC for storage in batteries. This will also allow for peak demand that is greater than the generator capacity.

#### Wind generator pollution

Wind generators can make noise and can have a significant visual impact. These may be an issue with neighbours. The impact may influence decisions about wind generator location, size and height. Noise can be generated from the turbine blades, gearbox (if used), and brush gear, as well as from wind moving past the tower and guy wires.

## 3.5 Solar

New Zealand does not have solar thermal power stations as are being built in other parts of the world. Without these, in New Zealand nearly all of the solar energy that is directly used to heat buildings, photovoltaic systems, hot water, etc, whether by good design or otherwise, is not measured. Therefore the amount of such useful energy is not recorded. This then becomes part of the energy reduction or energy savings. The potential benefits of quality design are very significant. This is discussed further in Section 5 of this report.


*Figure 3.13: Solar energy applications*

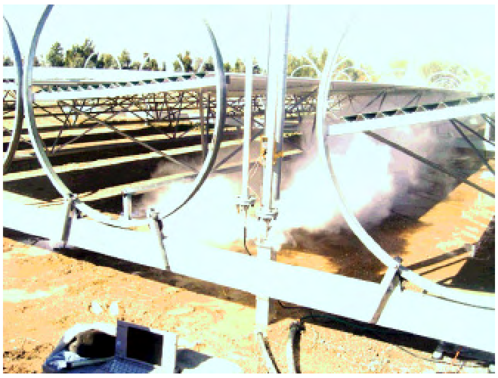

*Figure 3.14: Solar steam*

### 3.5.1 Potential for Passive Solar Building Design

Solar space heating can significantly reduce the amount of energy use in new buildings. With solar space heating, the building is designed to maximise the absorption of solar energy. This can be applied to any building regardless of size or use (domestic/commercial). The building design considers building placement and orientation on the site and design features to capture, store and release solar energy in the building. Solar building design not only reduces the energy use, but it also can reduce moisture and condensation, improve sound insulation and provide a generally more comfortable and healthy living environment.(SKM 2006)

### 3.5.2 Large-scale Solar Thermal

#### 3.5.2.1 Solar Tower

The sun's radiation is used to heat a large body of air under an expansive collector zone,

*Figure 3.15: Solar hot water*

which is then forced by the laws of physics (hot air rises) to move as a hot wind through large turbines to generate electricity. A 600m tall tower in Australia is underway (Figure 3.16).

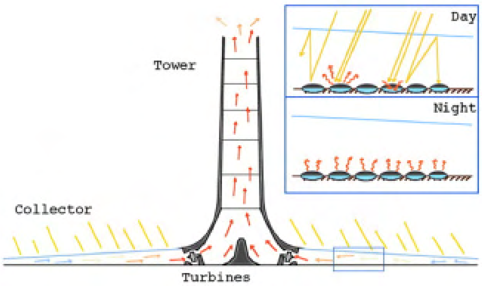


*Figure 3.16: Solar tower*

### 3.5.2.2 Solar Energy Generating Systems

Trough systems predominate among today's commercial solar power plants. Nine trough power plants, called Solar Energy Generating Systems (SEGS), were built in the 1980s in the Mojave Desert. These plants have a combined capacity of 354 MW making them the largest solar power installation in the world.

Trough systems convert the heat from the sun into electricity. Because of their parabolical shape, trough collectors can focus the sun at 30-60 times its normal intensity on a receiver pipe located along the focal line of the trough. Synthetic oil circulates through the pipe and captures this heat, reaching temperatures of 390°C. The hot oil is pumped to a generating station and routed through a heat exchanger to produce steam. Finally, electricity is produced in a conventional steam turbine. The SEGS plants are configured as hybrids to operate on natural gas on cloudy days or after dark, and natural gas provides 25% of the total output.

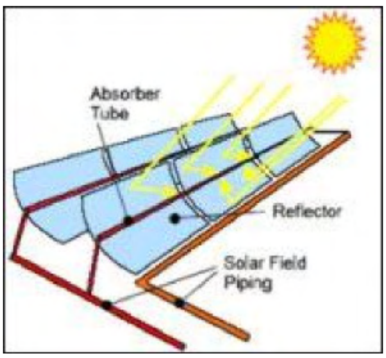


*Figure 3.17: Sketch of a Parabolic Trough Collector system*

*Figure 3.18: Photovoltaic panels on roof*

(http://en.wikipedia.org/wiki/Solar_power_plants_in_the_Mojave_Desert)

In Australia a medium-sized (50 MW equivalent) solar steam generating system is being built for power augmentation (booster) systems to deliver steam into an existing fossil-fuelled power plant, increasing power output and reducing carbon emissions. Many proponents of renewable energy hope that the concept may be a major step in finally moving towards coal-free power generation (Figures 3.14 and 3.17).

### 3.5.3 Solar thermal conversion

Technology used in solar thermal conversion systems continues to advance, reducing production cost and increasing system performance. Ongoing improvements to solar conversion surfaces and effective reductions in convection losses ensures solar thermal conversion efficiency continues to improve (SKM.) For Solar hot water systems – see Section 5.

### 3.5.4 Potential for Solar Thermal

Households account for 42% of electricity demand in the Canterbury Region (EECA, 2004). Of this, about one third is usually for water heating (BRANZ 2004). A standard solar thermal system can produce around 55% of a household's water heating. Solar thermal systems are most economic when installed in new buildings. Population growth in the Canterbury Region has been 8.6% for the 2001 to 2006 period (Statistics NZ 2006). The number of occupied dwellings increased by approx. 14,000 with the largest growth occurring in the Waimakariri and Selwyn Districts. The areas with high demand in new housing and are best suited for promotion and installation of solar thermal systems. Overall, there is potential for a substantial increase in the uptake of solar thermal use in the Canterbury region. (SKM 2006)

## 3.5.5 Photo-voltaic (PV)

Whilst sunlight is free, collection and transfer to usable power requires technological advancement before this form of energy can take its place as a commercially viable renewable energy source. Advances in PV technology are now at point where thin film products can be moulded into building components. Costs have been lowered to US$2/W. Construction of production plants is well advanced and due to begin manufacture in 2009. Large scale installations by utilities have booked all production capacity until the end of 2010. The long run cost as sales volume and production capacity increases is expected to drop to NZ$2,000/kW (compared with $7,000 currently) assuming power system connected i.e. no batteries. At this level PV will be lower cost than centralised grid connected generation options and mass market installation is likely to be triggered. PV systems interconnected to each other via the existing electricity infrastructure do not need battery storage.

It should be noted that the arrival of this technology to the mass market will coincide with the arrival of affordable electric car technology. These two technologies complement each other in that cars will have battery storage.

### 3.5.5.1 Infrastructure implications for expected PV growth

The implications for infrastructure are:

- The electricity network will need to be adapted from one way power flow distribution to a more dynamic and active network providing reliability services and managing net power flows.
- Domestic consumers will have more self sufficiency and so less expensive security provisions will be required.
- Bulk users of power will become the main users of the network in its current mode. Infrastructure will adapt to their specific requirements.
- Different pricing methodologies will be required and the industry structure and markets will change.
- Role of the transmission grid similarly changes.

### 3.5.5.2 PV growth

Photovoltaics (PV) is one of the more direct methods of harnessing the sun, and a plentiful energy supply. PV is undergoing quite a boom worldwide. Since 2000, production has been roughly doubling every two years, making PV the fastest-growing energy technology in the world. On the technical level, incremental advances in conversion efficiency, particularly with low-cost materials, are bringing both financial and environmental costs down. There are also newer approaches being investigated which could yield large jumps in efficiency, to as high as 60%.

As the technology develops, it will only become more attractive economically, and environmentally – the energy payback time for crystalline silicon PV cells has reportedly dropped from over 8 years in 2000 to about two years now. Installation of PV modules is undergoing rapid growth. Government policies like those in Germany and Australia are having major effects on uptake of the technology particularly at the small-scale level (Figure 3.18).

In these countries, financial incentives such as subsidies and feed-in tariffs (allowing PV owners to sell excess power back to the grid) are helping to ease the financial burden on investors. It is important to acknowledge the potential impacts of PV – there are potential health hazards of the PV and battery materials. PV remains one of the most promising options from the point of view of its low maintenance and quiet operation. Ensuring that buildings have adequate solar access and suitably designed roofs is a planning issue.

### 3.5.5.3 Earlier reports on PV were not as encouraging

- High costs and very limited capacity factor make photovoltaics not likely to be competitive as a grid connected energy source in the next 15 years. However summer air conditioning loads are increasing in Auckland, and may cause daytime peak loads where PV systems could usefully provide some peak shaving in future. (Emerging Supply-Side Energy Technologies MED, PB Power, July 2006)

- For the Canterbury Region, there is significant potential for solar thermal hot water systems but considerably less for solar photovoltaic. (Canterbury RREA – SKM July 2006)

The biggest barrier for the large scale uptake of PV is the high cost of the technology. Consequently, uptake has predominantly been for remote power supplies, enthusiast users and commercial developments where renewable energy has additional value as a corporate strategy or image statement. In summary, *the current high costs of solar photovoltaic means that large scale grid connected uptake in the region is unlikely in the short term, however small scale applications, particularly for remote power supply are expected to become more popular.* (SKM 2006)

### 3.5.5.4 Recent PV developments

Dr. Martin Green was awarded a Zayed Future Energy Prize on the eve of the 2009 World Future Energy Summit in Abu Dhabi in January 2009, for leading the way in solar technology. Dr. Green's achievements in photovoltaic solar energy will drastically increase the economic feasibility of this technology. Dr. Green's research has enhanced the viability of photovoltaic solar energy conversion as a large-scale, sustainable energy source for the future. His breakthroughs have moved the industry closer to reaching the full potential of photovoltaics, by reducing cost and increasing overall efficiencies. Dr. Green is currently developing 'third-generation' solar cells that will help decrease costs to less than US$0.50/W, to potentially $0.20/W or better, which will drastically increase the economic viability of this technology.

Dr. Green is Scientia Professsor at the University of New South Wales, Sydney and Executive Research Director of the University's ARC Photovoltaics Centre of Excellence. He is the Research Director of Sydney-based CSG Solar Pty Ltd. This company's formation in 1995 commercialised his group's research on silicon polycrystalline thin film solar cells in the largest investment in renewable energy technology in Australia's history. His contributions have also improved the performance of silicon solar cells by over 50 percent, improvements that have also been commercialised largely in Europe and China.

The photovoltaics market is currently booming as a result of growing international market initiatives, with most of the product sold being "first generation" solar cells relying on the use of expensive silicon wafers. Potentially much lower cost "second generation" thin-film technology, where the photoactive material is deposited directly onto a supporting substrate is now starting to appear on the market. The future depends on streamlining the costs of such thin-film approaches while improving the solar energy conversion efficiency. Particularly important may be "third generation" approaches which are thin-film approaches incorporating advanced schemes for improving this energy conversion efficiency beyond that possible with traditional approaches, such as on "all-silicon" tandem cells and "hot carrier" cells.

On 25 February 2009 First Solar Inc. (Arizona, United States) announced it had reduced its manufacturing cost for solar modules to US $0.98/watt, breaking the $1 per watt price barrier that the industry has been striving towards in recent years. It is confident that further significant cost reductions are possible based on the yet untapped potential of its technology and manufacturing process.

Manufacturing capacity has grown to more than 500 MW in 2008 and annual production capacity will double in 2009 to more than 1 GW, the equivalent of an average-sized nuclear power plant. These manufacturing costs demonstrate the ability of thin film PV technology to provide an alternative to traditional fossil fuels.

The actual panel will cost more like US$2 to $3/watt. Still, compared with a coal-fired power plant at US$2.10/watt (which does not account for fuel or any potential carbon price) it is a great step towards subsidy-free solar power. California utilities must comply with a state mandate to produce 20 percent of their power from renewables by 2010 and then 33 percent by 2020. Utilities also benefit from a 30 percent tax credit for building solar installations.

**3.5.5 5 Passive Solar Building Risks – impacts, visual, audio, pollution, environmental issues**

There are no particular risks associated with good design using solar other than loss of access to solar energy.

**3.5.5 6 Solar Steam & Energy Generating System Risks – impacts, visual, audio, pollution, environmental issues**

*Impacts*

- These are typically sited in desert type areas with plenty of sunshine.

*Visual*

- Large areas of land are required to be covered with solar collectors.

*Audio, Pollution, Environmental issues*

- No significant issues known

**3.5.5 7 Solar Thermal Conversion Hot Water System Risks – impacts, visual, audio, pollution, environmental issues**

*Impacts*

- Roof structures and connections need to be strong enough to support the relatively light solar collectors
- Solar access, and shading from buildings and trees

*Visual*

- On new buildings these collectors can be part of the roof cladding.
- More obvious for retrofit.

*Audio, Pollution, Environmental issues*

- No significant issues known

**3.5.5 8 Photo-voltaic (PV) Risks – impacts, visual, audio, pollution, environmental issues**

*Impacts*

- Large areas of walls and roofs are being clad in Germany

*Visual*

- This is typically never an issue.

*Audio, Pollution & Environmental issues*

- There are potential health hazards of the PV and battery materials
- The use of rare metals being developed as catalysts is a concern as world supply of these is limited.
- No other significant issues known

# 3.6 Wood (Biomass)

## 3.6.1 Examples of a life cycle analysis of woody residues to consumer energy in Canterbury

The use of forest residues as a source of energy products is attractive because, as a by-product of forestry operations, forest residues do not use additional land. This is important where land competition is present between (for example) dairy, forestry, food crops or energy crops. It is estimated that a forest residue resource of 26PJ/annum is currently available in New Zealand. The six energy product pathways analysed are listed in Table 3.2.

Life Cycle Assessments (LCA) of six possible pathways to energy-related products from wood residues are shown in Table 3.3.

**Potential scale:** For New Zealand, up to 3.372 million ha of forest producing up to 600 PJ p.a. of primary energy.

## 3.6.2 Examples of a life cycle analysis of purpose grown forest to consumer energy in Canterbury

This section considers the products of the six energy product pathways, where the wood is sourced from a forest grown specifically for

| Pathway name | Conversion technology | End product(s) |
|---|---|---|
| Combustion | Combustion | Heat |
| Cogeneration | Combustion | Heat and electricity |
| Ethanol | Enzymatic hydrolysis | Ethanol |
| Gasification – combustion | Gasification | Heat |
| Gasification – cogeneration | Gasification | Heat and electricity |
| Gasification – Fischer Tropsch | Gasification + Fischer Tropsch | Biodiesel |

*Table 3.2: Pathways to energy product production from forest residues*

| | Combustion Heat | Combustion CHP | Ethanol | Gasification Heat | Gasification CHP | Gasification Biodiesel |
|---|---|---|---|---|---|---|
| EROEI[1] | 7.5:1 | 4.9:1 | 3.5:1 | 5.6:1 | 4.0:1 | 3.9:1 |
| Greenhouse gas reductions[2] | 92% | 94% | 75% | 90% | 83% | 83% |
| Cost ($/GJ) | $15.60 | $27.60 | $59.40 | $31.20 | $42.00 | $34.50 |
| Technology status | Mature | Mature | Developing | Developing | Developing | Developing |

1 Energy Return on Energy Investment (EROEI)

2 Compared with heat from coal, electricity from the grid and fossil transport fuels

*Table 3.3: Woody residues – energy balance, GHG emissions, other environmental benefits, economics, technology status*

energy product production (see Table 3.2). Purpose-grown forest would allow for large scale energy production. In this scenario, all the costs and environmental burdens of forestry are attributed to the wood used to make bioenergy, and all wood is hogged in an electric hogger/chipper located at the conversion facility.

The goal of this section of the study was to develop a Life Cycle Assessment profile of the greenhouse gas emissions, embodied energy, and costs associated with the generation of energy product from purpose grown forest. It also allows the comparison of costs and impacts of energy product production from purpose grown forest with energy products from forest residues. The results are shown on Table 3.4.

**Potential scale:** For New Zealand current 26 PJ p.a. of primary energy, rising to 46 PJ p.a. by 2030.

### 3.6.3 Conclusions for wood production

Overall, the cost of producing energy from a purpose grown forest is greater than for forest residues, but the embodied energy, (not including stored solar energy) and greenhouse gas emissions are smaller. The greenhouse gas emissions are lower because the energy inputs to creating the resource are also lower, due to a more efficient supply chain being enabled with a large scale process.

The production of energy from a purpose-grown forest is more expensive than from forest residues, as the cost of all forestry operations are now attributed to the wood, whereas in the case of forest residues there was no economic value given to the residues. As the energy and greenhouse gas emissions of forestry was allocated to the forest residues on a mass basis, there is no difference in the burdens of forestry in forest residues and the purpose-grown forest.

In addition, no transport of wood within the forest is required for purpose-grown forest, whereas landing residues must be transported to the diesel hogger located within the forest in the forest residue pathways.

| | Combustion Heat | Combustion CHP | Ethanol | Gasification Heat | Gasification CHP | Gasification Biodiesel |
|---|---|---|---|---|---|---|
| EROEI | 10.9:1 | 6.9:1 | 4.5:1 | 7.7:1 | 5.5:1 | 5.4:1 |
| Greenhouse gas reductions* | 95% | 91% | 80% | 93% | 89% | 89% |
| Cost ($/GJ) | $34.50 | $54.80 | $86.60 | $53.20 | $72.60 | $65.40 |
| Technology status | Mature | Mature | Developing | Developing | Developing | Developing |

* Compared with heat from coal, electricity from the grid and fossil transport fuels

*Table 3.4: Purpose grown forest energy balance, GHG emissions, other environmental benefits, economics, technology status:*

### 3.6.4 Wetbacks*- wood stove to heat water

Recent moves by the Ministry for the Environment to limit urban air pollution has provided a discouragement to install wood stoves with water heating capability. This has arisen due to concern that the presence of a water jacket within the firebox reduces the efficiency of combustion and thus raises smoke emissions. However, newer designs providing either a coil of pipe within the upper chamber of the stove or a water jacket around the flue largely bypass this problem.

Wood stoves have the potential to provide more than 'boosting'. A stove with a 3 kW wetback run for 6 hours a day should obviate the need for any other source of water heating in all but the largest households during winter. Thus an ideal set up for most family homes would be solar plus wetback.

There may be a case for mandatory installation of wetbacks of approved design. This needs to be balanced against less than ideal placement of the tank and the possibility that home owners may choose another form of space heating to avoid the extra cost. However, there is also a case for providing a subsidy to cover this cost – in terms of cost effectiveness, it may well provide at least as good an investment of public funds as a solar heater**. SEF suggests the Department liaise with MfE and EECA on these issues.

### 3.6.5 Wetbacks - wood stove to heat water Risks – impacts, visual, audio, pollution, environmental issues

*Impacts*

- Poorly designed units need to be replaced to limit urban air pollution

*Visual*

- The sight of flames and burning fuels is attractive to many people.

*Audio*

- Natural burning sounds should be no concern.

*Pollution*

- Appropriate testing for compliance with set limits of emissions

*Environmental issues*

- Burning firewood is considered carbon neutral and typically uses materials that would otherwise be wasted and left to rot and decay giving off methane etc.

## 3.7 Land Use – Crop Residue (Biomass)

### 3.7.1 Example of a life cycle assessment of straw CHP in Canterbury

A 33 MW plant capable of generating 33 GWh of electricity and 327 TJ of heat per year from 40 000 tonnes of straw within a 60 km supply radius was assessed. From the study the following is a summary:

- Potential scale of resource: Significant regional resource, 0.6 PJ electricity and 1.8 PJ of heat from 210 000 tonnes of straw/ year in Canterbury
- Energy balance: has an Energy Return on Energy Investment (EROEI) ratio of 17.6:1
- GHG emissions: greater than 90% reduction in comparison with coal for heat and grid electricity
- Other environmental benefits: avoids burning crop stubble
- Economics: currently not economically viable in comparison with coal for heat and grid electricity
- Technology status: mature

(Forgie V. and Andrew R. Landcare Research May 2008. Lifecycle assessment of using straw to produce industrial energy in New Zealand. Report prepared for the Bioenergy Options for New Zealand – Pathways Analysis project.)

### 3.7.2 Example of a life cycle assessment of Canola to biodiesel in Canterbury

Biodiesel is a high-quality fuel that is widely

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* The term 'wetback' does not correctly describe this design. However the word is in common parlance and is used here as a term for a device that extracts heat from a wood stove to heat water.

** It is noted that, in general, subsidies may be unnecessary if the line company ODV valuation methodology was modified to recognize the national economic benefits that would result from reduced losses and less pressure to invest in network expansion.

accepted in Europe and North America. The creation of biodiesel from oily plant material (seeds and nuts) is a straightforward process based on common technologies that are well developed. Glycerol is a key co-product of biodiesel production that provides a cost offset.

The best potential source of biodiesel in New Zealand has been identified as canola crops. Canola is a brassica crop that produces seeds with oil content from about 40%–46%, at 8% moisture content.

The area most suited to growing canola in New Zealand is on the Canterbury Plains of the South Island. Canola has previously been grown in New Zealand to produce cooking oil, and has been grown as a fodder crop for stock. The oil in canola seeds is most commonly extracted either mechanically in an oil press or chemically with a solvent. Normally 65%–80% of the oil can be extracted in an oil press. After the oil has been extracted the most valuable by-product is a protein-rich canola meal, which can be sold for stock food to dairy and beef farming operations.

*Summary*

- Potential scale of resource: 39 PJ of liquid fuels (1.1 billion litres, assumes maximum crop area of 1 million ha).
- Energy balance: has an EROEI ratio of 2.2:1
- GHG emissions: 62% reduction in comparison with fossil diesel
- Economics: currently economically viable but depends critically on the price of canola seed, the use of residual meal for stock food, and the price of glycerol.
- Technology status: mature

# 3.8 Biofuels (Biomass)

## 3.8.1 Pathways for Bioenergy in New Zealand

A pathway is defined in this context as the route from raw resource through some conversion process to a consumer energy product (heat, power or transport fuel). For example; farm dairy effluent through anaerobic digestion to an ICE and producing on farm (distributed) heat and power. The following article discusses current issues with production of biofuels.

| Raw Material | Conversion | Energy Product |
|---|---|---|
| Wood residues | Combustion | Heat<br>Combined heat and power |
| | Enzymes | Ethanol<br>Biobutanol |
| | Gasification | Combined heat and power |
| | Gasification + Fischer Tropsch | Biodiesel |
| | Pyrolysis/oil | Combined heat and power |
| Effluents, industrial,<br>farm waste effluent,<br>municipal biosolids | Anaerobic digestion/gas | Combined heat and power<br>Gas for transport<br>Liquid fuels |
| | + Algae anaerobic digestion/gas | Combined heat and power |
| | + Algae chemical mechanical | Biodiesel |
| | + Algae/supercritical water | Liquid fuels |
| Agricultural residues (straws) | Combustion | Heat |
| | Enzymes | Combined heat and power<br>Ethanol and biobutanol |
| | Gasification + Fischer Tropsch | Biodiesel |
| Horticulture residues (fruit wastes) | Anaerobic digestion/gas | Combined heat and power |
| | Enzymes | Ethanol |
| Agricultural crops (canola) | Chemical mechanical | Biodiesel |
| Waste oil | Chemical mechanical | Biodiesel |
| Landfill gas | Capture | Heat and power |
| Tallow | Chemical mechanical | Biodiesel |

*Table 3.5: Potential Bioenergy Pathways*

## Biofuels: Promise or Fantasy?

*by David Painter*

Biofuels have had a lot of publicity recently. Some of it has been wrong. Oxfam's recent report concluded that biofuel policies deepen poverty and accelerate climate change. The Parliamentary Commissioner for the Environment said the Biofuels Bill should not proceed,but Air NZ intends to use 10% biofuel by 2013. Earthrace just broke the round-the-world powerboat record, publicising biofuel.

Confused? Here are some facts, fallacies and fantasies.

Fossil oil is biofuel. Fact. Fossil oil was formed by micoscopic marine organisms trapped in geologic formations millions of years ago and subjected to extreme heat and pressure. Other biofuels are recent. Fallacy. Rudolf Diesel ran his first engine in 1895 on peanut oil, and said in 1912 that such oils could become as important as petroleum and coal tar products. Henry Ford designed his Model T to run on a petrol-alcohol blend, "the fuel of the future".

Peak oil is here. Fact. Arguing when peak oil will occur or whether it has occurred is pointless. Cheap fossil oil is no more. World transport fuel problems will be solved by... hydrogen fuel cells, electric cars, 'water motors', etc. Some take too long to implement. Others violate science.High prices for fossil oil, economic problems and rationing will occur. Fact. A top USA analyst expects an oil-induced financial crisis about 2010 to 2015, which will last at least 10 or 12 years. US consumers will pay NZ$5.20 per litre at the pump. It will be more in New Zealand.

Biofuel production increases food prices. Fact and fallacy.  This is fact for biofuel made from food crops (first generation) or on food production land. Second generation biofuels don't use edible crops. Biofuel production causes deforestation. Fact and fallacy. It is fact for biofuel made from non-forest crops such as babassu palm, which displaces forest as in South-East Asia, but not generally. Recent US and European Union biofuel policies increased food prices and deforestation. Fact. Over-enthusiastic politicians adopted biofuel-encouragement policies when only first-generation biofuels were available.

There are huge reserves of [...] to quickly replace fossil oil. [Insert] shale oil, tar sands, methane hydrates, etc. Fallacy. Peak oil is about volume, but also ease, cost and rate of recovery. Some reserves take more fossil energy to recover than new energy obtained, and not quickly. The best contribution to New Zealand's transport fuel challenge will be conservation. Fact. It means using cars less, public transport more, more fuel-efficient transport, alternative energy sources and appropriate urban design and infrastructure.

Biofuels increase fuel prices. Fallacy. Almost half of Brazil's vehicle fuel is sugar-cane bioethanol, which costs NZ$45 a barrel, while oil is NZ$180. The Gull Oil blend in New Zealand of 10% Fonterra bioethanol and petrol, costs slightly less than petrol. Fossil oil will increase. Biofuel will decrease with second-generation biofuels and scale economies. Government intervention is unnecessary; the market will provide. Fantasy. State organisations control much world oil production. Global oil companies still maximise profitsfrom selling fossil-oil products. They have no incentives to treat the small New Zealand market generously.

New Zealand has great renewable energy. Fact. We have a steep, wet, sunny, windy, fertile country and a long coastline. Transport fuel is a special, difficult case, needing high energy per volume, safety and affordability. Biofuels will ease the difficult readjustment from fossil oil plenty. NZ is active in biofuels research. Fact. The Government's main 2008 research round allocated 9%, or $40 million, of all contestable funding to biofuels research. The Biofuels Bill will make matters worse, affecting atmospheric carbon, deforestation, land use and food prices. Fallacy. The Bill now requires biofuels to meet “specified environmental or sustainability standards or specifications”.

There is still much oil; high prices result from producers playing the market, oil companies profiteering and the actions of commodity speculators. Prices will fall and business will resume as usual. Fantasy. The first sentence is probably correct, but see the “peak oil” and “high prices” facts, and the “solved by” and “quickly replace” fallacies. Business as usual is a fantasy. Richard Branson’s Virgin Atlantic Airline was the first to fly with biofuel, on 24 February 2008. Fact and fantasy. A Virgin Atlantic Boeing 747-400 flew from London to Amsterdam that day. One of four fuel tanks contained a blend of 80% fossil-oil-derived fuel and 20% vegetal oil-derived fuel. So 5% of the fuel was biofuel, for a 400 km flight in an aircraft with a 14,000 km range.

Air NZ will this year become the first airline to test second-generation biofuel, made from jatropha nut oil. Not yet fact or fallacy. Air New Zealand requires future fuel to be: “environmentally sustainable and not compete with food; at least as good as today’s JetA; significantly cheaper than that and readily available.” This Boeing 747-400 flight will use oil from jatropha grown in South-East Africa or India. Will it really occur this year, go a reasonable distance with one engine running on 100% jatropha-derived fuel, satisfy the airline’s requirements and New Zealand’s expectations for sustainability and social effects?

New Zealand can produce rapeseed biodiesel, as in the European Union. Fact and fallacy. We can and are (Solid Energy subsidiary Biodiesel NZ), but should not. It is a first-generation feedstock that competes for arable land with food and could interfere with seed crops. New Zealand can produce sugar cane bioethanol, as in Brazil. Fallacy. New Zealand can not grow sugar cane. Using crops like sugar beet or sorghum would still compete with food production.

New Zealand can produce maize bioethanol, as in the US. Fact and fallacy. We can, but should not. It is energy inefficient and contributes to world-grain price increases. New Zealand can produce wasteland-willow bioethanol, and simultaneously save Lake Taupo from excess nutrients. Fact and fallacy. Cellulosic materials such as maize, need more energy for processing than sugary feedstocks.

Lignin materials, such as cane willow, need even more. New Zealand can produce useful biodiesel from waste cooking oil and tallow. Fallacy. Commercial New Zealand biodiesel production started this way. There is insufficient waste cooking oil to contribute significantly to fuel needs and better things to do with tallow, at better prices, as Environment Canterbury discovered in its biodiesel bus trial.

Biodiesel is just diesel, produced from crops and animals. Fallacy. Biodiesel is usually produced from vegetal or animal oils by base-catalysed transesterification, producing monoalkyl esters. It is an international specification fuel which can be blended with diesel or used straight in diesel engines, but it is not diesel. More biofuel can be produced from aquatic microalgae than from land-based crops occupying the same area. City sewage ponds can be used to grow the algae. Facts. Microalgae are phenomenal biomass producers. Compare rapeseed at 1200 litres of biodiesel per hectare a year, maize at 3000 litres of bioethanol, sugar cane at 6000 litres, and jatropha or babassu palm oil at about 2000 and 4500 litres of biodiesel, with pond-grown microalgae at more than 30 000 litres of oil.

New Zealand company Aquaflow Bionomic produced the world’s first biodiesel from wild algae in 2006. Fallacy. Christchurch’s Solvent Rescue produced biodiesel from sewage pond algae in 2003. It was probably done earlier in Japan, Israel or the US.

Oil like fossil oil can be produced synthetically. Fact. The Fischer-Tropsch process used by Germany in the 1939-1944 war to make oil from coal is still used in South Africa. For energy and carbon reasons it is not a good solution for New Zealand. Other options, including liquefaction of biomass, show great promise.

Round-the-world record-making 100% biodiesel powerboat Earthrace sourced enough fuel from body-fat liposuctioned from crew and volunteers to propel it for 15 km of its 24,000 km journey. Fact, but irrelevant. It illustrates one difficulty in basing serious discussion of biofuels in New Zealand's transport fuel future on over-hyped publicity in media-sized bites.

These are items I have reacted to in television, radio and print. Which are facts, fallacies or fantasies, and the comments, are my opinions. Biofuels are neither good nor bad. They have an important transitional role in New Zealand's transport fuel future.

Biofuel production can be good or bad; it is subject to commercial, regulatory and social pressures.

*David Painter is a Christchurch consulting engineer and former university academic. He worked on biofuels from crops in the 1970s and 1980s, and has more recently been involved in oil from algae developments. This article originally appeared in the Christchurch Press and has been reproduced with permission of the author.*

Given that we need to have at least the option of alternative energy supply to the BAU case, it is worthwhile to consider which pathways are going to work for bioenergy in New Zealand. Having defined what resources are significant in volume (forest and other wood residues) or environmental impact (effluents) we then decide what possible options (conversion) there are for their use, and how they compare to each other. Pathways that are likely to work in New Zealand, that will meet a demand, cost effectively and energy efficiently (NB – not necessarily now but in 2020/2030) are presented in Table 3.5. (Derived from *Bioenergy Options reports and Bioenergy Workshop*, November 1 2007, Wellington.)

### 3.8.2 Converting biomass into energy

Biomass can be used to produce heat, power and liquid fuels, along with other products. Energy products from biomass can be produced in a range of forms (solid, gas, liquid) which can be handled by existing infrastructure in many cases.

Biomass has advantages over fossil fuels because it:

- is renewable.
- produces less greenhouse gas.
- is widely distributed.
- utilises and/or mitigates wastes.

The logical route for biomass resources is largely for heat and liquid fuels, with some ancillary electricity.

Energy outputs can be derived from biomass using a range of existing or developing technologies. Conversion technologies commonly used in New Zealand to produce heat, biogas and biodiesel include combustion, anaerobic digestion and chemical/mechanical methods. Emerging technologies for the production of liquid biofuels include gasification (+ Fischer Tropsch), enzyme technology and pyrolysis.

The use of biomass resources, which are diverse and widely distributed, is technically feasible, but costs are highly variable.

Significant barriers are:

- guaranteeing quantity and quality of biomass feedstock supply to conversion plant.
- achieving economic scale.

### 3.8.3 Research directions

To realise the potential of using these technologies to convert biomass into energy, the following research needs have been identified:

- Woody biomass: All facets of growth, harvest, delivery, processing and conversion, driven by the relative importance of residual resource and potential to develop a purpose grown resource. Technology areas would be gasification with combined heat and power, gasification to liquid fuels and enzyme technology. Improvement of data in some areas is required.

- Life cycle analysis (LCA) and costings and the development of New Zealand centric LCA databases.
- Anaerobic digestion of effluents and wastes including gas productivity, catalysts, scale and environmental benefits.
- Algae: The potential to utilise nutrient rich waste waters from anaerobic digestion and the production of both biogas via digestion and production of biodiesel.
- Pyrolysis technology and the potential of biochar as a carbon store.
- Social, environmental and economic impacts of bioenergy.
- Policy mechanisms and effects.
- Carbon capture and storage.

Any shift from fossil energy to bioenergy will require much more than research. Technology demonstration, infrastructure, industry partnership, the right policy environment and consumer perceptions must all be addressed.

The full set of reports underpinning this summary is available on CD along with maps and tables of resource distribution. This document represents the first stage of an ongoing project. The next report arising from the Bioenergy Options study will further explore the concepts raised herein.

### 3.8.4 Bio-diesel and Ethanol

There is considerable potential to use biodiesel fuel as either a stand alone or supplementary fuel in vehicles and generators. Biodiesel can be produced from a wide range of organic matter including plants, crops, effluent, algae, wastes and used cooking oil. The potential of bio-diesel as a renewable energy source is considerable and is being rapidly developed elsewhere in the world now that the cost is competitive at $60/oil barrel equivalent.

However, careful consideration shall be given to trade-offs between competing land use such as dairying, forestry, other food crops, urban expansion, water use implications, as well as $CO_2$ emissions associated with the production process. Note that ethanol production is complementary with the use of grain for animal feed. Animals can't digest the cellulose component of grains that is used for fuel production. This can be processed out of the grain prior to feeding without detrimental degrading of the food value. The animals produce less waste and methane as a result.

Currently almost all of New Zealand's ethanol for fuel blending is derived from whey with current production approximately 16-20 million litres/year. Ethanol blends of up to 10% can be run in fuel injected petrol cars without mechanical modifications. However, it should be noted that internationally ethanol fuelled vehicles capable of running on 85% blends or greater are now being factory produced. The New Zealand Government has now mandated the use of biofuels in the New Zealand transport fleet. [*This policy has recently been reviewed.*] Current New Zealand regulations allow for up to 10% ethanol blend with petrol and 5% biodiesel blends for retail purposes, although mandated levels are less. It is also interesting to note that up until the 1930s New Zealand produced a significant proportion of its liquid fuels from sugar beet crops. The development of large scale production and bulk shipping tankers made importation of oil more economic. This economic equation has changed recently.

http://www.caenz.com/info/publications/newsletters/downloads/ID44.pdf

## 3.9 Energy from Waste

### 3.9.1 Waste to Renewable Energy: Burwood landfill Gas to QE II

At Burwood landfill methane was a problem; as organic material rots in an oxygen-free environment, so landfill gas, including methane (approx. 59%), is produced. To destroy the gas the solution is normally to collect and burn it off in a flare. Instead of regarding the landfill gas as a worrisome item to eliminate, landfill gas may be used in sustainable projects to generate heat and electricity. In the case of the gas from Burwood landfill, the gas is piped 3.7 km underground to the QE II swimming pool and sports complex after a simple drying process that takes place at the landfill site (see Figure 3.19).

At QE II, the landfill gas is fed into two boilers


*Figure 3.19: Burwood landfill gas treatment plant*

and a cogeneration plant which produces both electricity and heat (Figure 3.20).

Previously the boilers were fired using LPG; there is still an LPG tank on site for use when the pipeline or the plant at the landfill undergoes maintenance.

Although the landfill gas is a free source of renewable energy, the City Council still had to ensure that capital investment in the project would be worthwhile. The calculations and measurements showed that savings would result in a payback for the project of about 4 years. As part of the calculations was the concept that the City Council could sell the carbon credits generated from destroying a greenhouse gas, methane. The City Council received 200,000 credits from the government's Projects to Reduce Emissions Programme. The revenue from these credits ($3.5 million) will be used to fund the Sustainable Energy Strategy for Christchurch 2008-2018.

Methane has a global warming potential of 22, meaning that every kilogram of methane emitted to the atmosphere has the equivalent forcing effect on the Earth's climate of 22 kilograms of carbon dioxide.

### 3.9.2 Incineration-based Waste-to-Energy Technology

Despite being an attractive technological option for waste management, combustion-based processes for municipal solid waste (MSW) treatment are a subject of intense debate around the world. In the absence of effective controls, harmful pollutants may be emitted into the air, land and water which may influence human health and environment. Although incineration of municipal waste coupled with energy recovery can form an essential part of an integrated waste management system, yet strict controls are required to prevent its negative impacts on human health and environment.

Incineration technology is the controlled combustion of waste with the recovery of heat to produce steam that in turn produces power through steam turbines. MSW after pretreatment is fed to the boiler of suitable choice wherein high pressure steam is used to produce power through a steam turbine. Pyrolysis is extensively used in the petrochemical industry and can be applied to municipal waste treatment where organic waste is transformed into combustible gas and residues. Gasification is another alternative which normally operates at a higher temperature than

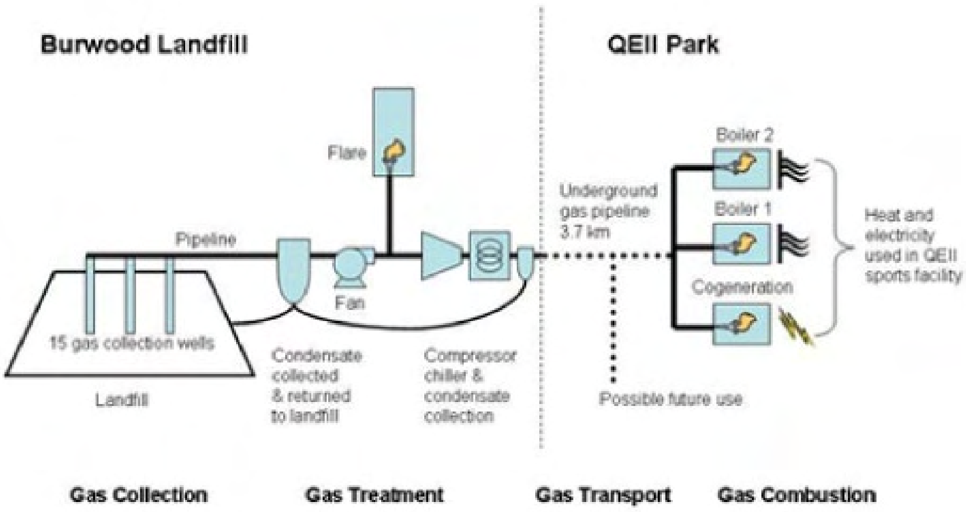



*Figure 3.20: Burwood/QE2 Park gas process*

pyrolysis in limited quantity of air. While both pyrolysis and gasification are feasible technologies to handle municipal waste, commercial applications of either technology have been limited.

Incineration-based technologies have been a subject of intense debate in the environmental, social and political circles. This article evaluates incineration on the basis of three parameters – environmental, human health and economic impact – and proposes an integrated mechanism to maintain a fine balance between energy recovery and environmental concerns.

**Conclusions**

The adoption of alternative cleaner methods for the disposal of municipal garbage is necessary. According to the United Nations Environment Programme (UNEP), incinerators are the leading source of dioxin into the global environment. The EPA, in a recent study, identified dioxins as the cause of many cancers, the worst component being TCDD (also known as Agent Orange).

The need for low-cost solutions presents significant difficulties, but it is not an impossible task. The ideal resource management strategy for MSW is to avoid its generation in the first place. In 1993, a Royal Commission on Environmental Pollution in England issued a four-stage decision procedure of which the first two stages state:

- Wherever possible, avoid creating wastes
- Where wastes are unavoidable, recycle them if possible.

This implies changing production and consumption patterns to eliminate the use of disposable, non-reusable, non-returnable products and packaging.

An integrated solid waste management (ISWM) is essential to establish a waste hierarchy to identify the key elements. The general hierarchy should be comprised of the following order:

1 Reduce
2 Reuse
3 Recycle
4 Waste minimization and recovery of energy from waste by composting, anaerobic digestion, incineration etc.
5 Landfilling

The cost of building and operating incinerators or providing special landfill sites is enormous. If substantial parts of these funds were to be diverted towards waste minimisation and encouraging recycling, the need for waste disposal could be enormously reduced, apart from reducing the dangers which arise from both incineration and landfill. It is essential to explore the potential of environment-friendly technologies, like anaerobic digestion (AD), for the treatment of municipal waste because it holds the promise to address two highly important environmental concerns - waste management and renewable energy.

September 8th, 2008. http://www.alternative-energy-news.info/negative-impacts-waste-to-energy/

### 3.9.3 Anaerobic Digestion

Anaerobic Digestion has a great future amongst the biological technologies which will become the tools for sustainable waste management throughout the 21st Century, working with nature to maintain the natural carbon cycle to the benefit of man.

Anaerobic digestion (AD) is a biological process similar in many ways to composting. It is a natural treatment process and, as in composting, bacteria break down organic matter and reduce its bulk or "mass".

Unlike composting AD is carried out in an oxygen-free environment (known as anaerobic conditions) to allow the presence of bacteria adjusted to these conditions which then multiply and grow, and by so doing achieve the process aims of:

- sanitisation of the feed material and of any liquid discharged;
- a net positive surplus generation of energy as a biofuel to allow power production from methane gas (biogas) produced by the organisms.

Products of Anaerobic Digestion:

- A gas: Methane - a fuel.
- Solid fibrous material; which is spread without further treatment, or after post

composting (maturation), to provide organic matter for improvement of soil quality and fertility (improves soil structure and reduces summer irrigation demand).

- The liquid fraction contains two thirds of the nutrients and can be spread as a fertiliser and sprayed on crops.
- Co-composting on farms - liquid and solid fraction is mostly not separated and is spread as a slurry.

**A Comparison of Anaerobic Digestion with Composting**

See Table 3.6.

In the UK there is great potential to generate revenue from the AD of organic wastes. Using all agricultural waste produced there is the capacity to generate twice the energy requirement of the agricultural sector. At current renewable energy electricity market prices, there is an opportunity to make £10 to £20 from only one tonne of organic waste. http://www.r-e-a.net/biofuels/biogas/anaerobic-digestion/ad-energy-balance.

**Christchurch City Council - Solids treatment**

Raw sludge from the primary sedimentation tanks and the biological solids from the final clarifiers are pumped into large enclosed heated tanks called digesters. Two of these digesters operate at 55°C and four operate at 38°C. Bacteria that thrive under these conditions break down the organic matter over a period of days, releasing carbon dioxide and methane, and changing the decaying solids into 'biosolids' that are applied to land as a fertiliser. The methane produced in the digestion process is used as a fuel for engines, producing power for the plant and the national grid. Heat recovered from the engines is used to heat the digesters (see Figure 3.2.1).

| | **Anaerobic Digestion** | **Composting** |
|---|---|---|
| Space requirement (footprint) | 50% | 100% |
| Odours | 20% | 100% |
| Energy balance | Energy surplus | Energy demand |
| Biogas production | 100 – 150 $m^3$/Mg | Nil |
| Process time required to produce mature compost | 3 weeks digestion, plus5 weeks composting | 12 weeks |

*Table 3.6: A Comparison of anaerobic digestion with composting (Source: "Introduction to Anaerobic Digestion",Wolfgang Muller and Axel Huttner, ORA - Organic Resource Agency Ltd., Malvern Hills Science Park, Geraldine Road, Malvern, Worcestershire WR14 3SZ, and IGW – Ingenieurgemeinschaft Witzenhausen Fricke & Turk, and GmbH, Bischhuser Aue 12, D-37213 Witzenhausen, Germany. Presented at the Biowaste: Digesting the Alternatives Seminar, April 2005, UK.) http://www.anaerobic-digestion.com/html/introduction-to-anaerobic-dige.html)*

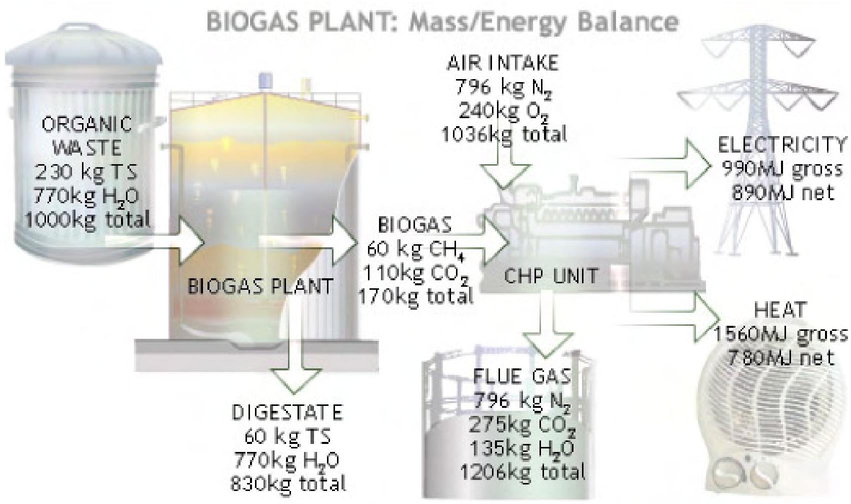



*Figure 3.2.1: Christchurch City Council biogas plant*

Operating data (2006/2007):

- Suspended Solids Received: 56.8 tonnes/day
- Gas Production: 15,392 $m^3$/day
- Annual Electricity Production: 11,250,000 kWh
- Connected Population: 323,019

**On-farm waste-to-energy solution**

An on-farm energy system BioGenCool transforms cow effluent into power that is used to heat and cool while providing a greatly reduced electrical load. Ian Bywater has painstakingly and carefully researched and developed the system with the intention of how technology can deliver energy from renewable sources, at low-cost and with benefits to the environment through a reduction in greenhouse gas emissions. The BioGenCool process extracts the biogas (methane gas and carbon dioxide) from the cow effluent using novel biodigester technology.

After production it is then cleaned and used as a fuel in a co-generation plant to generate electricity. The process converts the volatile organics into biogas, leaving the resulting supernatant liquid low in bacteria, nitrogen rich, cleaner and more readily assimilated than raw manure. This therefore makes it paddock ready for disposal around the farm.

The conversion of the biomass produced by a typical dairy herd is sufficient to provide the energy to meet most of the demand for vacuum pump, hot water and milk chilling requirements. The quality of milk is directly related to the temperature at which it is stored. Currently in NZ most milk is stored at below 7 degrees C, though an EU Standard requires that milk be stored at 3 degrees C. The BioGenCool system provides rapid efficient cooling to 3 degrees C using a secondary heat exchange subsystem and delivers milk for transportation that is foam free. Technical director Ian Bywater reports that a farmer with 850 cows could save up to $30,000 a year in electricity costs. The Canterbury project has been very successful and fully demonstrates how BioGenCool can save up to 35% of the energy used in the dairy shed. In addition to this there are savings in water consumption through recycling by using 'greenwash' in the dairy shed yard.

(http://www.naturalsystems.co.nz/BioGenCool.html)

## 3.10 Gas

The South Island currently does not supply nor consume any natural gas in any form, and so it is also the case for Canterbury. Liquefied petroleum gas (LPG) is available and used mainly in the industrial and commercial sectors but also in households and for transport. The latter application was popular in the 1980s in the aftermath of the oil crises of the late 1970s. However, with the withdrawal of government subsidies, the transport use of LPG has declined substantially. There is now a resurgence in interest due to LPG prices becoming more competitive due to sustained high oil prices. LPG is regarded as an 'oil' in standard energy accounting.

Current government policy (Hon. Gerrry Brownlee, 24 February 2009):

*Thermal Ban*

'One of the first things the new Government did was to remove the ban on new thermal baseload electricity generation. The ban was a piece of political symbolism that endangered security of supply. The Government wants investment in new electricity generation to occur on the basis of sound economics, rather than through ruling out particular options on the basis of ideology.

Gas will be a big part of New Zealand's energy mix in the future. Gas already plays a vital "firming" role with hydro generation, and this will only increase in the future with intermittent generation such as wind coming into the system. New Zealand's electrical energy future will rely on more wind, hydro and geothermal. **Gas will bridge us to that future.'**
(www.beehive.govt.nz/speech/unlocking+new+zealand039s+energy+and+resources+potential)

### 3.10.1 Natural Gas

Most experts believe that there are still significant quantities of gas to be found in New Zealand. For a country that exhibits the

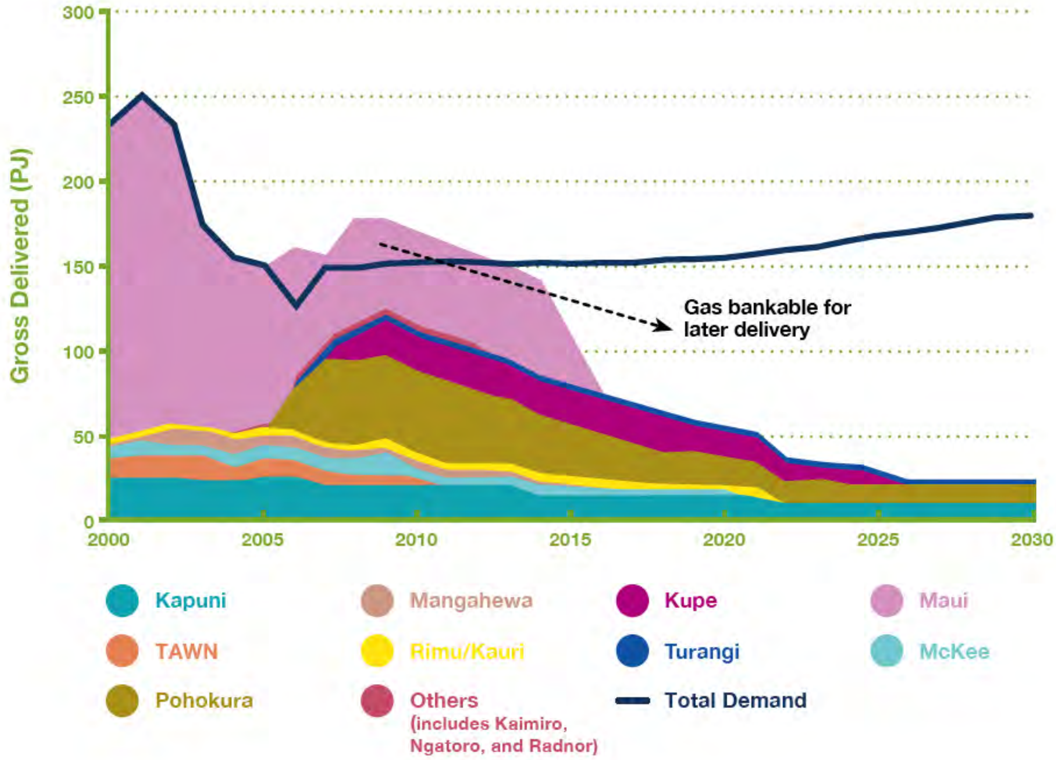



*Figure 3.22: Demand v Supply Profile for NZ Natural Gas (Source: MED New Zealand Energy Outlook to 2030). New Zealand is facing a potential shortfall in indigenous natural gas supply by 2015. The dark blue line indicates projections of total demand for gas, while the coloured profiles indicate supply available from New Zealand gas fields. The gas above the line before 2010 represents surplus gas that could be 'banked' for use in later years.*

promising “sedimentary basin” geology that is required for oil and gas deposits, New Zealand has been relatively lightly explored by international standards.

The biggest commercial barrier to significant gas exploration is New Zealand’s small population and remote location. If a petroleum company struck a large gas find, there is only so much consumption possible in New Zealand and it is not economically feasible to construct a gas pipeline to other parts of the world. Accordingly, a lot of gas finds have occurred whilst petroleum companies are searching for oil deposits, which are more easily tankered around the world if found.

Now that Maui is drying up (see Figure 3.22), we are starting to see the petroleum companies searching more specifically for gas again, with some drilling activity on the Taranaki continental shelf and interest in the Great South Basin below Stewart Island and the East Coast of the North Island. While it is likely that major gas reserves exist in other parts of New Zealand, the lack of existing infrastructure such as pipelines and customers means their exploitation is much less likely, especially for potential South Island reserves.

| | |
|---|---|
| **Huntly** | 48 MW OCGT Genesis 2006 Now operational |
| **E3P** | 365 MW CCGT Genesis End – 2006? Gas contract secured with Kupe JV |
| ***Rodney*** | 3 x 120 MW CCGT Genesis ? Gas supply would require pipeline connection to Wiri-Marsden Point (possibly upgraded) |
| ***Kaipara*** | ??? Todd ? Potential synergy with offshore Karewa and other fields |
| ***Southdown*** | 45 MW Mighty River Power? Announced 12 July 2006 |

*Table 3.7: New and Planned Gas-fired Generation Capacity.*
*Note: OCGT: Open-cycle gas turbine; CCGT: closed-cycle gas turbine.*

**Security of supply:** While it is likely that significant quantities of gas will be found in New Zealand, there is considerable uncertainty as to whether they will be found in time, given the long lead times associated with developing fields. And accordingly, gas from New Zealand gas fields scores poorly on the security stakes, given the relatively high probability of the energy gap not being closed in time.

**Price:** If sufficient gas is found in time, domestic gas is probably one of the cheapest options for New Zealand. However, if it isn't found in time and New Zealand is relying on it, then prices are likely to climb steeply as the balance between supply and demand becomes extremely tight towards the end of this decade. Even if gas is found in time, it is unlikely to be as cheap or flexible as gas from the Maui gas field.

**Environment:** The "only" significant environmental impact from gas is the carbon dioxide ($CO_2$) that is emitted. Modern combined-cycle gas fired power stations emit two-and-a-half times less $CO_2$ than a modern coal-fired power station.

http://www.contactenergy.co.nz/web/view?page=/contentiw/pages/savetheplanet/gas&vert=sp

A number of new and planned gas-fired generation plants are being developed (Huntly and E3P) or have been announced (Table 3.7).

### 3.10.2 LPG

Liquefied petroleum gas (LPG) is the only available gaseous fuel (a mix of hydrocarbons, mainly 60 per cent propane and 40 per cent butane) in the South Island. When these mixtures are lightly compressed they change from a gas state to a liquid.

Reticulated gas within Christchurch City started in some new urban land developments a few years ago, with bulk storage within the subdivision.

There is often an expectation that LPG prices should fall when petrol and diesel prices fall. However LPG prices are set differently so LPG and petrol or diesel prices don't change at the same time. LPG prices are not directly linked to oil prices. LPG (Liquid Petroleum Gas) is not derived from oil, which means there's no direct link between LPG and petrol or diesel prices. So if the price of petrol comes down it doesn't mean LPG will also go down. However, like petrol and diesel, LPG is affected by the laws of supply and demand. When oil and refined fuel prices increase, demand for cheaper LPG also increases, which leads to higher international LPG prices. When global fuel prices fall, LPG prices don't drop at the same rate as oil and refined fuel as the pricing mechanism is very different.

LPG prices are set internationally, not locally

Since 2008 New Zealand has set the retail price for LPG according to an international contract price with the addition of shipping costs, local taxes, an importer margin and adjustments for the current exchange rate. Prior to 2008 LPG prices were set locally based on New Zealand's cheap, but diminishing, LPG supplies. This kept pump prices fairly flat. However we now import more than half of what we consume.

### 3.10.3 LNG

Liquefied Natural Gas (LNG) is simply that - natural gas which has been cooled to the point where it turns into a liquid. Such liquefaction is undertaken by countries with surplus gas reserves which then ship it in specially built tankers around the world to purchasing countries. It is then 'regasifed' in special terminals and injected into their "normal" gas pipeline network. The global LNG market is mature, with significant quantities being traded. The most likely sources of LNG that could be purchased for New Zealand would be Australia or Indonesia.
(www.contactenergy.co.nz/web/view?page=/contentiw/pages/savetheplanet/liquifiednaturalgas&vert=sp)

Most LNG is traded under long-term contracts, typically of 10-20 years duration. Spot trading in LNG remains relatively modest, so some basis other than spot LNG prices must be found for setting LNG prices under these contracts. Although LNG (and natural gas generally) competes with both oil and coal in the electricity generation and direct-use markets, LNG is usually viewed as a premium fuel, like oil, due to its relative cleanliness, ease of use and ability to be transported by sea over long distances. For these reasons, and the fact that Japan initially imported LNG partly to substitute for oil-based fuels, oil prices have historically been used as the basis for setting the price of LNG in the Asia-Pacific region under long-term contracts.

Some of the key developments of the last 2-3 years are discussed below.

- Oil prices have continued to be high and volatile. Earlier this year (11 July) the West Texas Intermediate (WTI) marker peaked at US$147/bbl. Partly due to the effects of the credit crisis, prices have since dropped to around US$60/bbl at the time of this writing.
- At this oil price level, LNG prices are around US$10/mmBTU, still high by historical standards
- Infrastructure projects, including oil and gas extraction and processing plants, have faced rapidly escalating costs, for both materials and personnel. Greenfield LNG liquefaction capacity installation costs have increased from around $500/t/year or less 3-4 years ago to over $1000/t/year today.
- In broad terms, the uncertainty of rising infrastructure development costs and other factors such as resource or environmental issues, have meant that few LNG liquefaction plants have achieved final investment decision (FID) status since 2005. In 2007, there were over 10 projects awaiting FID yet only two, Pluto in Australia and Angola LNG achieved that status. Even for plants that have achieved FID, construction periods have stretched from around 3 years duration to longer than 4 years. Hence any plant approved now is not likely to enter into production until 2012 at the earliest.
- The credit crisis and slowing global economic growth, combined with retreating oil and gas prices, are resulting in a very uncertain environment for financing additional LNG capacity
- As a result of increasing demand not being fully met by increased supply, higher prices may be expected in the long-term in both oil and LNG (and to some extent pipeline natural gas) markets.

An LNG pricing report 'A Formula for LNG Pricing' prepared by consultant Gary Eng, was updated in November 2008 to reflect recent changes in the world gas and oil markets. http://www.med.govt.nz/templates/MultipageDocumentTOC_39562.aspx

### 3.10.4 Coal Seam Gas (CSG)

Coal seam gas (or coal bed methane) is largely the same as conventional natural gas and occurs naturally in coal seams. Electricity from coal seam gas is now on the national grid. New Zealand has a new source of electricity following the connection to the national grid of a 1 MW generator driven by coal seam gas from Solid Energy's pilot field near Huntly in the Waikato. Coal seam gas provides 15-20% of gas supply in the United States and Australia's eastern states, with the figure climbing to 70% in Queensland. (www.scoop.co.nz/stories/BU0811/S00432.htm)

L&M Petroleum Ltd., the exploration company seeking to commercialise coal-seam gas from its permit areas in Southland, report that extended laboratory tests of coal samples from its Goodwin-1 well has confirmed the presence of gas. Tests showed that coals in the Goodwin-1 well contain up to 4.4 cubic metres of methane per metric ton. The tests indicate between 78% and 98% of the gas-in-place is potentially recoverable. The company is awaiting tests in the next few weeks of samples from a second well in the vicinity, Wairaki-1.

http://business.scoop.co.nz/?p=2298 (Jan 14, 2009)

Larger scale production and suitable applications could mean that gas from such sources may eventually be available to Canterbury consumers.

## 3.11 Oil

### 3.11.1 Oil in New Zealand

Oil is the largest single source of consumer energy, with about half the market. Most of this oil is used in transport, as stationary uses for oil have almost disappeared over the past 30 years. Although New Zealand produces some oil, it is heavily dependent on imports. Netting imports and exports of crude oil and oil products, New Zealand is only about 20% self-sufficient in oil. http://www.med.govt.nz/

upload/38641/eo-2006-final.pdf

Oil is New Zealand's largest and arguably most problematic energy source. Policies related to oil have wide impacts, including those on the economy, the environment, consumers, foreign affairs, and transport planning. Because of their wide impact, issues related to oil frequently attract great public interest and, sometimes, contentious debate. Yet oil is also a sophisticated industry, and to usefully contribute to the dialogue requires a certain level of technological, economic, and institutional knowledge that can appear daunting to the newcomer. *Oil: An Introduction for New Zealanders* by Ralph Samuelson provides an easy-to-read background briefing for anyone who will be dealing with oil-related policy issues (http://www.med.govt.nz/templates/StandardSummary_37607.aspx).

### 3.11.2 History of oil development in New Zealand

New Zealand has produced a modest amount of domestic oil since its first well was drilled in Taranaki in 1866. However, it has been heavily dependent on oil imports since essentially the beginnings of the industry. The oil shocks of the 1970s hit the New Zealand economy very hard. These were especially difficult times, since the oil shocks coincided with the end of New Zealand's special trading relationship with the United Kingdom, as the UK entered what is now the European Union. The period in the early 1980s saw petrol prices rise to over $2 per litre in today's terms. From 1975 to 1985, transport energy demand showed little change.

After the oil shocks, the government aggressively intervened to reduce dependence on imported oil. It encouraged the use of CNG and LPG as transport fuels and developed the Motunui synthetic petrol plant. The plant met about one-third of the country's petrol requirements during its peak production in the late 1980s, but operated at a substantial loss that, at least initially, was paid by the government. Synthetic petrol production was phased out in 1997, although the plant continued producing methanol until 2004. In 1988, the government removed price controls on petrol and took further steps to deregulate the industry. The government has never had ownership interests in petrol distribution and retailing, unlike its interests in the electricity and gas sectors. New Zealand has one major refinery, at Marsden Point, which opened in 1964 and expanded in the late 1980s. The majority of the feedstock is imported.

### 3.11.3 Economic Significance of the Canterbury Basin

While the Canterbury Basin has drawn the attention and investment of oil and gas exploration ventures over many years, until a discovery of commercial scale is made and developed, the potential resources that are thought likely to exist can make no contribution to the regional energy system. Conversely, a discovery of scale sufficient to justify development could transform the regional energy situation.

The promising results of Galleon-1 in particular, attest to a reasonable level of oil and gas industry confidence in Canterbury's potential. Realisation of that potential needs to overcome significant risks and costs, not just in making a discovery but in its subsequent appraisal, development, and the associated development of an infrastructure for the processing and/or utilisation of production in the region.

### 3.11.4 Economic Impact Example

An indicative economic assessment assuming a successful discovery of 80 million barrels of oil in the Southern Canterbury Basin has been done. Some input assumptions, amongst others, include an oil price of US$45 per barrel, a gas price of NZ$5 per GJ and an exchange rate of NZ$1:US$0.60. A production profile for oil with associated gas and water based on Taranaki Basin 'F-Sands' type reservoirs, is assumed, resulting in an economic field life of at least 8-10 years. With a site just 23km offshore east of Oamaru and in around 75 m water depth, it may be regarded as a 'near shore' prospect. Thus production could start within a year of discovery should a commercial find be made. Based on development costs of US$410 million and operating expenditure of US$90-100 million p.a., the success case NPV is estimated at around US$610 million (around NZ$1 billion) with a field value in excess of US$7.50 per barrel. Even though the oil is likely to be directly loaded on to tankers from a floating production, storage and offloading (FPSO) facility and shipped elsewhere for further processing, these figures clearly imply significant economic benefits for the region from the exploration, appraisal and, especially if successful, production phases of such discoveries.

More importantly, any successful discovery is likely to improve the prospectivity of the Canterbury Basin, eventually leading to more successful discoveries. It is the aggregate effect of such discoveries that may transform the energy supply picture and energy infrastructure of the Canterbury region, in particular, and that of the South Island.

As exploration and research programmes advance, understanding of New Zealand's sedimentary basins and their petroleum systems continues to evolve. The important geological elements and the timing of generation, migration and accumulation of hydrocarbons are now broadly understood, enabling a more methodical approach to identification and appraisal of prospects. Coupled with increasing levels of exploration over recent years, this has led to an enviable success rate for wildcat drilling and a recent commercial discovery success rate of one in three in Taranaki Basin. Ongoing exploration can be expected to lead to further finds here and in other basins.

It appears likely that Canterbury will continue to have a heavy reliance on imported fuels, and in the future will remain a price taker with added cost from transport and distribution charges. The Canterbury basin offers the most significant prospective opportunity for the region in regards to new energy production. Any oil and gas discovery would transform the energy supply picture and energy infrastructure of the region. Currently all consumer oil products are imported into the region.

Confirmation of large oil fields in offshore water of New Zealand could provide a step change in national income for the country.

## 3.11.5 Transport Fuels

### 3.11.5.1 Production

World crude oil prices 1947-May 2008 are shown in Figure 3.23. Figure 3.24 shows indigenous crude oil, condensate and naphtha production produced in New Zealand, specifically the Taranaki production theatre, since 1970. Production has been dominated by the Maui Field, and to a lesser extent, the McKee Field, since the early 1980s.

Indigenous production peaked in 1997 at around 120 PJ but has now declined to less than half of the amount that prevailed during the 1990s. A combination of increasing consumption (as approximated by 'indigenous production + imports – exports'), as shown in Table 3.8, together with declining indigenous supply, means that import dependency has increased from less than 50% in 1985 to over 80% today.

### 3.11.5.2 Consumption

Table 3.9 shows the breakdown of transport energy fuels by mode. The greatest increases have been in marine (7.10%) and aviation (8.40%) with both having increases far greater than the total increase in transport energy consumption of 3.6%.

### 3.11.5.3 Prices

Figure 3.25 gives some indication of escalation in oil prices up to mid 2006, with the subsequent retracement back to around US$60 per barrel being a relatively small adjustment given the increase from less than US$30 per barrel to over US$70 over the period. Figure 3.26 shows how New Zealand crude and transport fuels prices have moved since April 2004. Consumer prices are muted because government taxes and levies comprise a significant share of the overall pump price and these do not vary much in the short term. For example, a price of $1.44 per litre for regular petrol is comprised of around $0.52 (41.7%) of taxes and levies. The two major factors that affect the short-term price of transport fuels such as petrol, diesel and aviation fuel are the price of crude oil and the exchange rate with the US dollar. A third component that varies with the vagaries of the oil-refining sector is the so-called refining margin.

For example, at an exchange rate of NZ$1:US$0.65, a US$1 per barrel change in the price of crude 'flows' through to (around) a 1c per litre change in the pump (retail) price of petrol or diesel, excluding GST. A 1c change (depreciation/appreciation) in the exchange

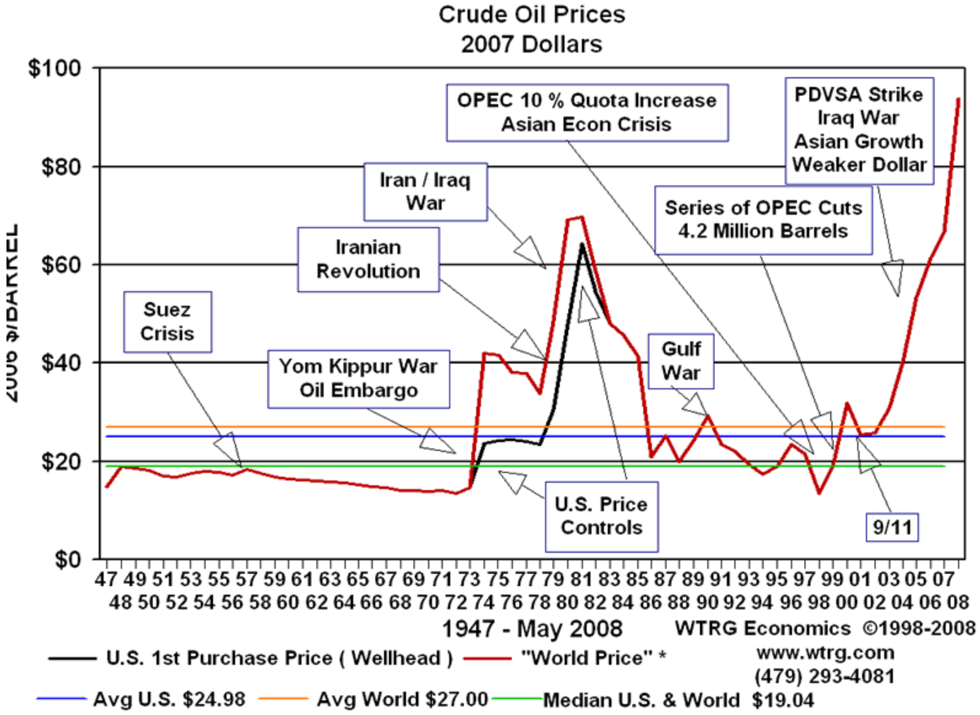
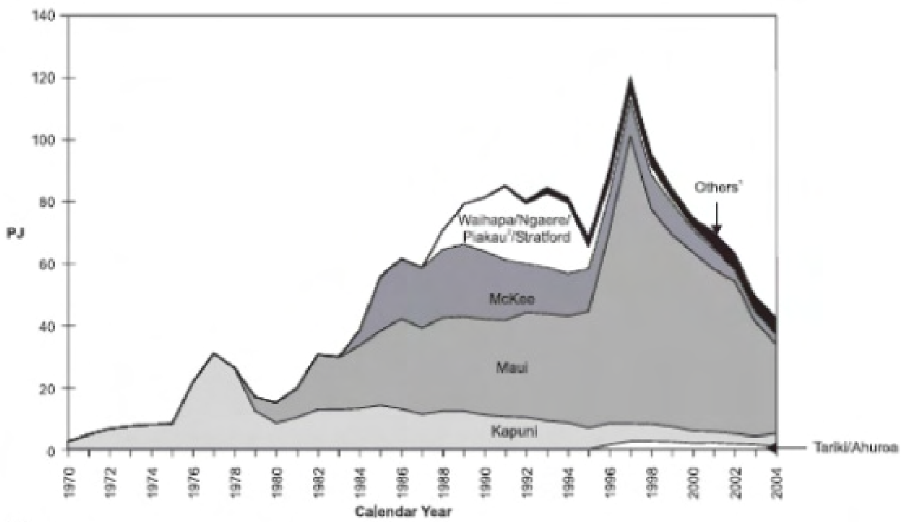



*Figure 3.23: Crude Oil Prices 1947 - May, 2008*




Notes:

[1] Includes Cheal, Kaimiro, Mangahewa, Ngatoro (including Goldie well), Radnor, Rimu (including Kauri well) and Stratford fields.

[2] Piakau has not produced gas since September 1999.

*Figure 3.24: Indigenous Crude, Condensate and Naphtha Production by Field (PJ)*

rate also affects the retail price of petrol by around (an increase/decrease of) 1c per litre, excluding GST.

Current retail prices also include a relatively high refinery margin, the fee that a refinery, such as that at Marsden Point, charges for refining crude into products. Worldwide refinery capacity expansion in the last few years has not kept up with the increase in (worldwide) products demand, resulting in refineries being able to charge more for their services. Thus, a situation of refining being a 'bad' business has turned around to a lucrative one until such time as capacity becomes more plentiful. As an illustration, the refining fee can range between 3c and 9c per litre and currently is at the top end of this range. An indication of the price components of (regular) petrol is shown in

| Calendar Year or ptember Years | New Zealand Production | Imports | Refinery Intake | Exports | Stock Change | Discrepan |
|---|---|---|---|---|---|---|
| 1985 | 55.73 | 40.18 | 64.56 | 29.02 | 2.56 | -0.23 |
| 1986 | 61.50 | 48.65 | 103.76 | 8.38 | -1.58 | -0.41 |
| 1987 | 58.69 | 104.34 | 152.68 | 4.66 | 4.80 | 0.90 |
| 1988 | 70.66 | 112.81 | 170.32 | 14.46 | -0.30 | -1.02 |
| 1989 | 79.17 | 137.88 | 188.46 | 27.56 | 1.35 | -0.32 |
| 1990 | 81.55 | 143.28 | 188.48 | 40.24 | -3.84 | -0.04 |
| 1991 | 85.28 | 143.84 | 182.52 | 44.88 | 1.97 | -0.26 |
| 1992 | 80.36 | 141.52 | 182.36 | 40.53 | 0.50 | -1.51 |
| 1993 | 84.70 | 158.38 | 192.28 | 47.58 | 0.25 | 2.97 |
| 1994 | 81.51 | 175.84 | 202.02 | 51.35 | 3.82 | 0.16 |
| 1995 | 68.33 | 169.37 | 196.28 | 44.11 | -2.05 | -0.64 |
| 1996 | 90.74 | 165.55 | 189.61 | 56.83 | 5.84 | 4.00 |
| 1997 | 120.56 | 168.30 | 212.29 | 77.70 | -1.11 | -0.02 |
| 1998 | 95.67 | 202.51 | 217.72 | 70.97 | 7.72 | 1.77 |
| 1999 | 84.36 | 198.77 | 212.72 | 63.45 | 3.14 | 3.82 |
| 2000 | 74.96 | 203.30 | 221.03 | 55.07 | 0.98 | 1.17 |
| 2001 | 70.02 | 191.46 | 208.93 | 58.12 | -6.61 | 1.05 |
| 2002 | 63.55 | 205.31 | 219.94 | 50.50 | -2.28 | 0.69 |
| 2003 | 49.20 | 217.66 | 220.10 | 41.85 | 5.47 | -0.57 |
| 2004 | 42.54 | 200.89 | 214.02 | 33.45 | -3.58 | -0.46 |

*Table 3.8: Crude Oil, Condensate, LPG and Naphtha Production in New Zealand*

| | Vehicle | Aviation | Marine | Rail | Total |
|---|---|---|---|---|---|
| | TJ | TJ | TJ | TJ | TJ |
| 1982 | 13,910 | 1,550 | 1,077 | 409 | 16,946 |
| 1983 | 13,962 | 1,768 | 1,656 | 425 | 17,812 |
| 1984 | 14,456 | 2,038 | 2,695 | 396 | 19,585 |
| 1985 | 14,066 | 2,341 | 3,043 | 431 | 19,881 |
| 1986 | 14,478 | 2,768 | 3,041 | 409 | 20,696 |
| 1987 | 14,495 | 3,380 | 3,308 | 418 | 21,602 |
| 1988 | 14,575 | 3,538 | 2,699 | 391 | 21,202 |
| 1989 | 14,831 | 4,014 | 2,802 | 374 | 22,020 |
| 1990 | 15,330 | 4,300 | 3,667 | 370 | 23,667 |
| 1991 | 15,627 | 3,919 | 4,502 | 354 | 24,402 |
| 1992 | 16,503 | 4,061 | 5,025 | 397 | 25,987 |
| 1993 | 17,186 | 4,542 | 5,255 | 397 | 27,380 |
| 1994 | 18,042 | 4,689 | 5,719 | 532 | 28,981 |
| 1995 | 18,586 | 4,987 | 5,817 | 594 | 29,983 |
| 1996 | 19,264 | 5,404 | 6,958 | 649 | 32,274 |
| 1997 | 19,879 | 5,436 | 7,525 | 647 | 33,487 |
| 1998 | 20,015 | 6,019 | 5,970 | 660 | 32,663 |
| 1999 | 21,243 | 6,026 | 4,763 | 674 | 32,705 |
| 2000 | 21,857 | 5,997 | 4,674 | 687 | 33,215 |
| 2001 | 22,521 | 5,552 | 4,914 | 701 | 33,687 |
| 2002 | 23,465 | 5,216 | 4,678 | 711 | 34,069 |
| 2003 | 24,096 | 5,490 | 4,320 | 728 | 34,635 |
| 2004 | 25,133 | 6,548 | 4,412 | 709 | 36,801 |
| (1983-2004) Mean Incr (%p.a | 2.70% | 7.10% | 8.40% | 2.90% | 3.60% |

*Table 3.9: Canterbury Transportation energy consumption by mode (TJ) [16]*

Figure 3.27. It is similar for premium petrol and also for diesel if the road user charge is included. There are little in the way of regional price differences within New Zealand. That is, freight costs to major population centres tend to be averaged out and consumers face the same prices in essentially all the urban centres. Some small centres and rural areas do face higher prices, which not only reflect some additional freight costs but also diseconomies of scale and possibly also a lack of competition. Despite the fact that the petroleum industry is wholly privately owned and, therefore, subject to commercial competitive practices and pressures, there is virtually no inter-company price differentiation at the retail level. For any price, change, there is usually an initiator and prices usually converge to an identical one within a short time.

#### 3.11.5.4 Prospects

It is probable that the days of (regular) petrol prices being below $1.30 per litre are behind New Zealand. With refining costs making up approximately 50% of the petrol price, as shown in Figure 3.27, and taxes being approximately 40% of the petrol price, the likelihood of prices falling significantly is much reduced. Although crude prices may fall significantly below US$60 per barrel in the medium term, a very likely lower exchange rate and a 'refinery margin' that is more sustainable for the refining industry, above the levels for much of the 1990s but perhaps slightly below current levels, are likely to put an effective floor on transport fuels prices. The possibility of a carbon tax would be an additional impost for the consumer. The consumption analysis of transport fuels shows it to be 'inelastic', especially in the short term. This suggests that consumer demand is relatively unresponsive to price changes, particularly price increases. Consumers are slow to react to higher prices, both in changing their behaviours and in changing their energy consuming 'assets'. All consumers have legacy assets and behaviours that take time to change. For example, plant machinery and buildings can only be replaced slowly, usually after some 'use by' date, which may be influenced by energy prices in a minor

| Petroleum Product | Lyttelton | Woolston | Chch Airport | Timaru | Total |
|---|---|---|---|---|---|
| | 000 / | 000 / | 000 / | 000 / | 000 / |
| 91 Octane Petrol | 22258 | 4071 | 0 | 13026 | 39355 |
| 95/96/98 Ocatane Petrol | 8913 | 2835 | 0 | 9500 | 21248 |
| Diesel/AGO | 23031 | 5009 | 9 | 17661 | 45710 |
| Light Fuel Oil | 9191 | 0 | 0 | 0 | 9191 |
| Heavy Fuel Oil | 4716 | 0 | 0 | 0 | 4716 |
| Jet Fuel - A1 | 25427 | 2999 | 3586 | 0 | 32012 |
| Avgas | 4640 | 0 | 58 | 0 | 4698 |
| Kerosene/DPK | 606 | 0 | 0 | 50 | 656 |
| Additives | | 25 | 0 | 27 | 52 |
| Lubricating oil | | 342 | 0 | 0 | 342 |
| Slops | 108 | 92 | 0 | 101 | 301 |
| Bitumen Products | 7921 | 0 | 0 | | 7921 |
| Total | 106811 | 15373 | 3653 | 40365 | 166202 |

*Table 3.10: (Maximum) Bulk Storage Capacities in the Canterbury Region [17]*

| | 2004 |
|---|---|
| | million litres |
| Transport | 1077 |
| Non-transport | 143 |
| Total | 1220 |

*Table 3.11: Liquid Fuels Consumption in Canterbury [18]*

| | Maximum Storage |
|---|---|
| | 000 litres |
| Lyttelton Port | 0 |
| Woolston | 2000 |
| in Lyttelton-Woolston Pipeline | 130 |
| *From Woolston* | |
| *- Rockgas Storage* | |
| Rockgas Ltd | 20 |
| Underground Storage | 500 |
| Harewood | 40 |
| Ferry Rd | 20 |
| Bryon St | 25 |
| *- Ongas* | |
| Ongas Ltd | 20 |
| Tumara Park | 20 |
| Canterbury Spinner Ltf | 20 |
| Total | 2795 |
| Total (tonnes) | 1500 |

*Table 3.12: Gas (LPG) Storage in Canterbury [19]*

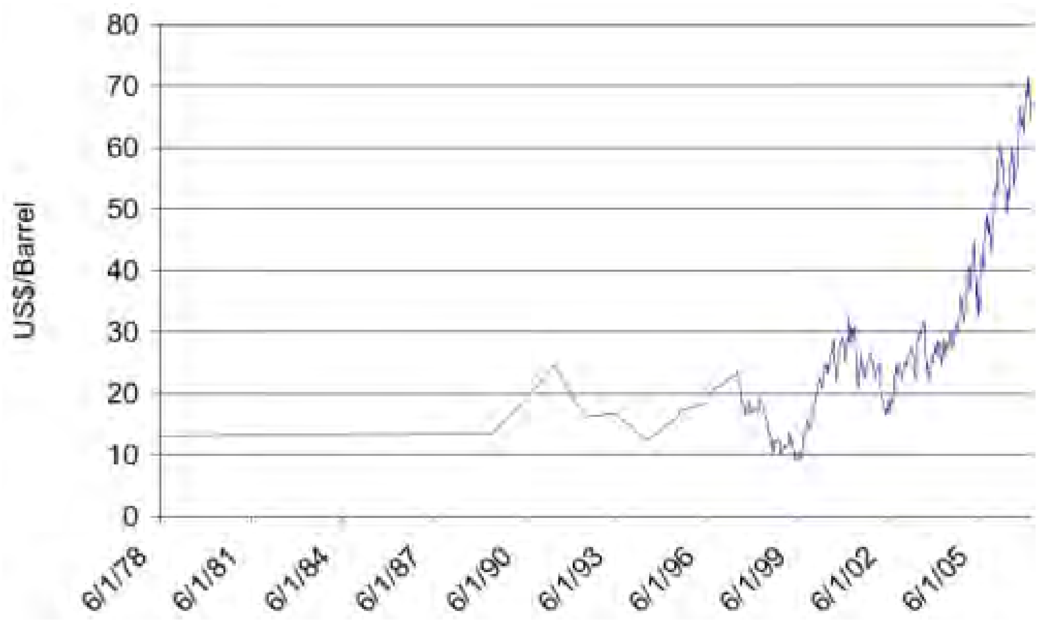



*Figure 3.25: Crude Oil Price (Average weighted by volume) [20]*

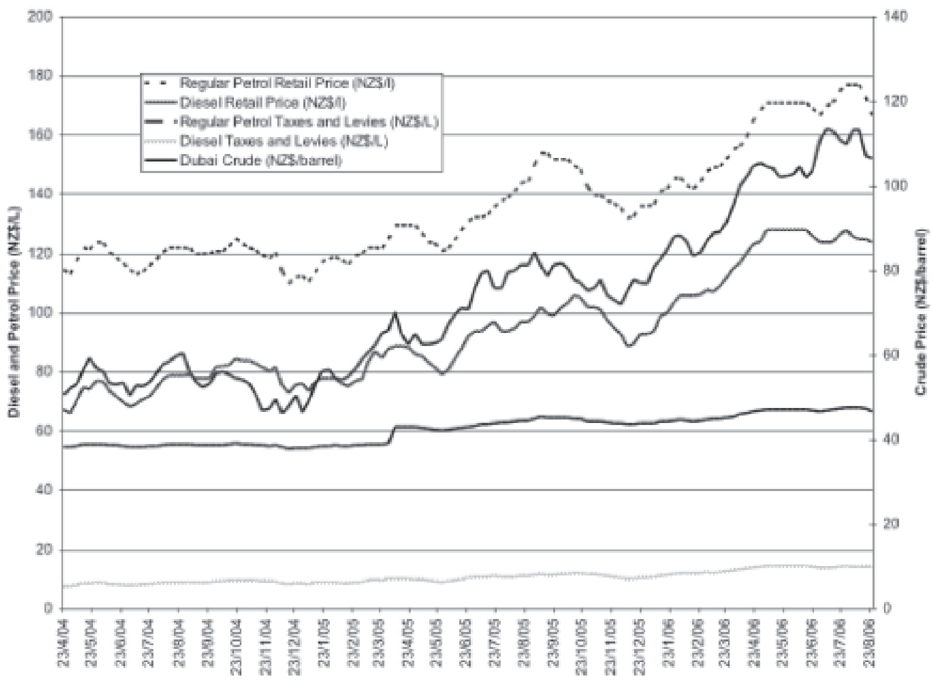



*Figure 3.26: Crude and Transport Fuels Prices in New Zealand since 2004 [21]*

way. For private motorists, the shift in recent years to more multi-vehicle households and to less fuel-efficient sports utility vehicles (SUVs) has proven costly in the face of very high fuel prices. In response, the shift to smaller vehicles and a decline in vehicle ownership intensity (where New Zealand is the third highest in the world behind the USA and Australia) and also to a lower usage of the private vehicle fleet, is and will be slow. Some consumers will be reluctant to forego the benefits that more and bigger vehicles provide. After a period of ostensibly non-responsiveness to higher prices, there is now likely to be some falls in the consumption of transport fuels as consumers have taken some time to adjust.

Even so, the trend for the consumption of transport fuels is likely to remain upwards as wealth and the demand for access to recreation and life style choices both increase. In the longer term, any shift to supplement traditional

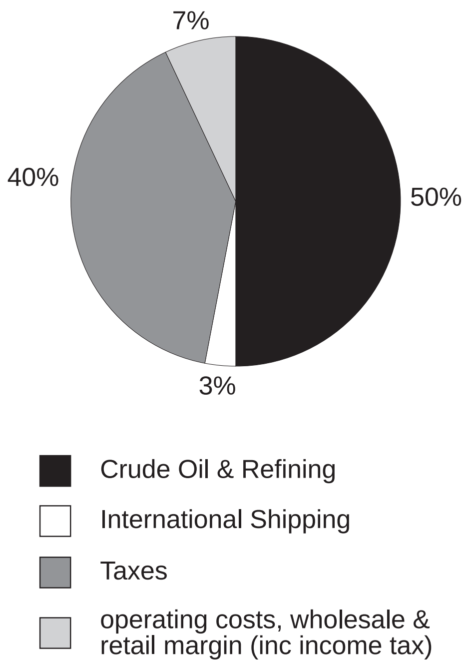



*Figure 3.27: Breakdown of Petrol Prices*

transport fuels by biofuels, other synthetic fuels or electricity will require either high oil prices to occur or government mandate. Any mandated measures are likely to create further upward pressures on prices.

### 3.11.6. Oil (Non-Transport)

Port sectors consume only 6-7% of overall oil consumption, with the other 93-94% being consumed in the transport sector. Since the South Island does not have reticulated natural gas available, the only available thermal fuels are coal and oil products. Notably, the consumption of LPG has been increasing strongly in recent years as shown in Table 3.13. The share of LPG in non-transport oil consumption has increased to around 50%, i.e., over 2000 TJ per year, of the total.

## 3.12 Coal

### 3.12.1 Production

New Zealand coal production in 2007 was 4.83 million tonnes. Almost all production is of bituminous and sub-bituminous coals, in approximately equal quantities.

Four underground and 21 opencast mines were operating in 2007. Solid Energy, owner of the two largest West Coast mines, was responsible for around 85% of the national production.

Production is centred on the Waikato (2.2 million tonnes), the West Coast (2.15 million tonnes), and Otago/Southland (0.47 million tonnes). Over 60% of national production was from two large opencast operations, at Rotowaro and Stockton.

### 3.12.2 New Zealand Coal Used

Coal supplies approximately 13% of New Zealand's primary energy supply or about 97 PJ/year. The biggest domestic user is the 1000MW Huntly power station (about 2.5 Mt/year, providing about 12% of New Zealand's electricity generation), followed by the Glenbrook steel mill (800,000 t/year). Coal is also used extensively in the dairy (300,000 t/year), cement (170,000 t/year), meat processing (120,000 t/year), timber and health industries. Over 70% of New Zealand's coal production for New Zealand use is from the Waikato. About 1 million tonnes of thermal coal is imported to the North Island each year, indicating a substantial domestic production shortfall. Coal Supplies of low-sulphur, low-ash coal are presently sourced internationally. This has exposure to international pricing and supply. New Zealand has large reserves of lower grade coal that could form a longer term energy supply if and when barriers to its extraction and use are resolved.

### 3.12.3 Exports

Premium New Zealand bituminous coals are valued internationally for their low ash and sulphur contents, and other characteristics such as high swelling, fluidity and reactivity, which allow them to be blended with other coals for use in the steel industry. Exports of bituminous coal, produced entirely from the West Coast, reached 2.2 million tonnes in 2008 through the Lyttelton Port of Christchurch.

New Zealand coal is exported mainly to India and Japan, with smaller quantities going to Chile, South Africa, Brazil, China, USA and Australia. Most exports are of coking coal, with smaller amounts of thermal and specialist coals. The Pike River mine has been developed for coking coal exports (opened November, 2008), and is on-track to hit its steady state production rate of 1 million tonnes per annum by mid 2009.

| | Ind'l/Comm | Residential | Total | % of Total Oil |
|---|---|---|---|---|
| | TJ | TJ | TJ | |
| 1982 | 3,840 | 78 | 3,918 | 11.4% |
| 1983 | 2,808 | 88 | 2,896 | 8.4% |
| 1984 | 2,662 | 75 | 2,737 | 7.5% |
| 1985 | 2,506 | 76 | 2,582 | 7.0% |
| 1986 | 2,132 | 78 | 2,210 | 5.8% |
| 1987 | 1,711 | 80 | 1,791 | 4.6% |
| 1988 | 1,529 | 77 | 1,606 | 4.2% |
| 1989 | 2,077 | 89 | 2,166 | 5.4% |
| 1990 | 2,279 | 90 | 2,369 | 5.6% |
| 1991 | 2,081 | 110 | 2,191 | 5.0% |
| 1992 | 1,786 | 138 | 1,924 | 4.3% |
| 1993 | 2,089 | 167 | 2,256 | 4.8% |
| 1994 | 2,338 | 201 | 2,539 | 5.2% |
| 1995 | 1,797 | 235 | 2,032 | 4.0% |
| 1996 | 1,118 | 271 | 1,389 | 2.6% |
| 1997 | 1,244 | 329 | 1,573 | 2.9% |
| 1998 | 5,466 | 383 | 5,849 | 10.0% |
| 1999 | 4,423 | 440 | 4,863 | 8.4% |
| 2000 | 3,751 | 518 | 4,269 | 7.2% |
| 2001 | 2,747 | 542 | 3,289 | 5.6% |
| 2002 | 3,465 | 603 | 4,068 | 6.7% |
| 2003 | 3,711 | 581 | 4,292 | 6.9% |
| 2004 | 3,645 | 612 | 4,257 | 6.6% |

*Table 3.13: Estimated Canterbury non-transport oil product energy (TJ)*

### 3.12.4 Government Policy - Carbon Sequestration (Hon. Gerry Brownlee)

"The Government is also interested in the possibilities of Carbon Capture and Storage, or carbon sequestration technology. If commercially viable CCS technology can be developed then it will be enormously beneficial to New Zealand.

Our total in ground coal resource is approximately 15.5 billion tonnes. Of this there are at least 6 billion tonnes of economically recoverable lignite. This equates to 74,000 petajoules or the energy content of 20 Maui gas fields. Last year I visited the Otway project in Victoria in which some government entities have had some involvement. I'll be interested to see how the government can be involved in supporting this exciting technology in the future".

http://www.beehive.govt.nz/speech/unlocking+new+zealand039s+energy+and+resources+potential (24 February 2009).

### 3.12.5 Liquid Fuels from Lignite

The report 'Liquid Fuels from Lignite' by CRL Energy, January 2008, examines the economics of producing liquid fuels in New Zealand from lignite, including greenhouse gas emissions and environmental impacts.

### 3.12.6 Integrated Gasification Combined cycle (IGCC)

IGCC technology could become competitive in the near term. Costs could match conventional coal fired plant, but generate power at higher efficiency. IGCC has lower emissions than conventional coal fired fired plant with flue gas treatment also very low. A key prospect for IGCC is the lower cost of separating $CO_2$ compared with other generation technologies, if carbon sequestion becomes a cost effective way to reduce carbon emissions.

### 3.12.7 Coal seam gas (CSG) – carbon neutral

The assessment of the coal seam gas potential has been undertaken in a staged programme. Preliminary assessment of the data on the permit areas indicates that the potential resource may be up to 500 PJ. To date, preliminary appraisals have been completed or are underway on a significant number of fields. Exploratory drilling has been completed or initiated on several of those fields, with results from this work being fed into the preliminary modelling as it has become available. Given that in many of these areas there is no pre-existing information concerning their gas potential and world wide experience with lignite is practically nonexistent, it has been a steep learning curve with many surprises. However, initial gas content results and preliminary gas flow models have been on the whole, rather pleasing, with the commerciality of some developments already apparent. [Waitaki report]

## 3.13 Nuclear Power

Advantages of nuclear power generation:

- Nuclear power generation does emit relatively low amounts of carbon dioxide ($CO_2$). The emissions of green house gases and therefore the contribution of nuclear power plants to global warming is therefore relatively little.
- This technology is readily available, it does not have to be developed first.
- It is possible to generate a high amount of electrical energy in one single plant.

Disadvantages of nuclear power generation:

- The problem of radioactive waste is still an unsolved one. The waste from nuclear energy is extremely dangerous and it has to be carefully looked after for several thousand years (10,000 years according to United States Environmental Protection Agency standards).
- High risks: Despite a generally high security standard, accidents can still happen. It is technically impossible to build a plant with 100% security. A small probability of failure will always last. The consequences of an accident would be absolutely devastating for humans and others. The more nuclear power plants (and nuclear waste storage shelters) are built, the higher is the probability of a disastrous failure somewhere in the world.
- Nuclear power plants as well as nuclear waste could be preferred targets for terrorist attacks. No atomic energy plant in the world could withstand an attack similar to 9/11 in New York. Such a terrorist act would have catastrophic effects for the whole world.
- During the operation of nuclear power plants, radioactive waste is produced, which in turn can be used for the production of nuclear weapons. In addition, the same know-how used to design nuclear power plants can to a certain extent be used to build nuclear weapons (nuclear proliferation).
- The energy source for nuclear energy is Uranium. Uranium is a scarce resource, its supply is estimated to last only for the next 30 to 60 years depending on the actual demand.
- The time frame needed for formalities, planning and building of a new nuclear power generation plant is in the range of 20 to 30 years in the western democracies. In other words: It is an illusion to build new nuclear power plants in a short time. http://timeforchange.org/pros-and-cons-of-nuclear-power-and-sustainability

### 3.13.1 The pebble bed reactor (PBR)

PBR is a graphite-moderated, gas-cooled, nuclear reactor. It is a type of Very high temperature reactor (VHTR) [formally known as the high temperature gas reactor (HTGR)]. The base of the PBR's unique design is the spherical fuel elements called "pebbles". These tennis ball-sized pebbles are made of pyrolytic graphite (which acts as the moderator), and they contain thousands of micro fuel particles called TRISO particles. This type of reactor is also unique because its passive safety removes the need for redundant, active safety systems. Because the reactor is designed to handle high temperatures, it can cool by natural circulation and still remain intact in accident scenarios, which may raise the temperature of the reactor to 1600˚C. Because of its design, its high temperatures allow higher thermal efficiencies than possible in traditional nuclear power plants (up to 50%), and has the additional advantage that the gases do not dissolve contaminants or absorb neutrons as water does, so the core has less in the way of radioactive fluids. http://en.wikipedia.org/wiki/Pebble_bed_reactor

At its current stage of development, the costs of Pebble Bed Reactors are too uncertain to determine if the technology will become competitive within 15 years. Nuclear power would probably only become acceptable as a response to reducing carbon emissions. In this context in New Zealand it would be competing with coal technologies that incorporate carbon sequestration.

### 3.13.2 Nuclear fusion plasma technology

This technology is being researched and developed – about 50 years or more away before commercially available. This is very advanced technology with extremely high temperatures. It is reported as a clean technology with no deadly waste.

### 3.13.3 Risks – impacts, visual, audio, pollution, environmental issues

"New Zealand has rejected for itself nuclear power generation. New Zealand does not consider nuclear power compatible with the concept of sustainable development, given the long term costs, both financial and ecological, of nuclear waste and the risk of nuclear proliferation." Treaty on the Non-Proliferation of Nuclear Weapons. Report submitted by the Government of New Zealand. First Preparatory Committee for the Eighth Review Conference of the NPT, 30 April – 11 May 2007, Vienna. http://www.mfat.govt.nz/downloads/global-issues/NZ-NPT-implementation-report.pdf

## 3.14 Other technologies

### 3.14.1 Fuel Cells

High costs at present, and progress on lowering costs is very slow. Not likely to be competitive as a grid connected energy source in the next 15 years. Some limited potential for distributed generation in the future because of high efficiency at small scale.

### 3.14.2 Micro-turbines (gas)

Micro-turbines are a distributed technology where combined heat and power production could provide the competitive edge. However at the small scale of micro-turbines, space heating is the predominant heat load and in new Zealand heating loads are often variable. Micro-turbines do not perform well under variable load conditions. Micro-turbines face strong competition from the established technology of gas reciprocating engines in landfill gas and other biogas applications.

### 3.14.3 Superconductors

High Temperature Superconductors are not likely to be competitive against conventional transmission lines or HVDC for long distance transmission. The technology is more likely to become commercial in reactive power control systems and other grid support systems. Areas where underground or underwater transmission is required will be the first applications where HTS may become competitive.

## 3.15 Renewable energy technologies including Small & Community Generation

The table (9 pages) in Appendix E provides in summary detail, a description, status, type of application, environmental effects and costs (2006) for each resource technology.

# 4 SUPPLY CHAIN

Energy supply chains transport and supply energy from the producers to the end users. Some energy transport forms are supplied in forms that can be collected, stored and even concentrated (e.g. Petroleum products). Other energy transport forms such, as electricity, must be used as it is generated, as it cannot usually be stored in a bulk form, which requires active demand/supply matching of the whole system.

## 4.1 Electricity

The electricity system in New Zealand is characterised by a long skinny high voltage transmission system that runs through the centre of the country. The transmission grid is connected between the North and South Island by a 1200 MW HVDC submarine cable link across the Cook Strait. Due to the geographical isolation of the country, there are no interconnections with other power systems.

Annual generation is approximately 41,000 GWh and is dominated by hydro- power, although this has decreased from approximately 75% in the 1990's to around 60% of total generation today. Other types of generation include gas, coal, geothermal, wind and various small scale biomass and solar.

Transmission of power is very important as the geographical generation centre is at Benmore in the lower South Island but the geographical demand centre is in Hamilton. This discrepancy requires electricity to be transmitted long distances across the system.

**Electricity Market:** The electricity industry in New Zealand has four main categories of market participation. These are: retail, distribution, transmission and generation. The participants that compete in the market are the retail and generation companies.

Transmission and distribution are considered to be natural monopolies and so operate their own networks within the regulations of electricity market. The wholesale market is the market in which generators compete to be dispatched and hence get paid by the market at the nodal price. Retailers and other purchasers such as major commercial and large industrial users buy electricity from the market at the nodal price. Every half hour each retailer submits a demand bid and each generator submits an offer of generation. The System Operator takes the demand bids and while considering security implications and operational parameters, dispatches the lowest cost generation, to met that demand, for that half hour.

The retail market is a market where electricity retailers compete for customers. Each retailer estimates their load and submits a demand bid to the system operator. At each network node, the purchases made by retailers from the wholesale pool are exactly matched to the physical demand uptake. Retailers can use financial instruments such as hedges to manage the risk of spot price variability but these are completely separate from the physical operation of the electricity system.

### 4.1.1Transmission & Distribution

The electricity transport infrastructure consists of two types of systems, transmission which represents the main grid (Transpower) connecting the large-scale generation in both islands to local sub-systems called distribution networks (Lines Companies) that connect to the local users.

Connection of a generator to either the transmission or a distribution network is required to transport the electricity to end users, other than local users. As such, these networks are an enabler of new generation and especially renewable generation, with its remoteness and requirements for geographic diversity and balancing. For many renewable projects, access to transmission/distribution and a largely unconstrained grid/network is a necessary pre-condition for generation investment.

An important characteristic for connection to these systems is the capacity of the lines and any constraints that may exist. Constraints are a limitation on the amount of power a line is allowed to carry before its normal operating conditions are exceeded.

A constraint can be caused by physical limitations (mainly due to heating effects on the lines, that cause them to stretch/sag, sometimes due to the maximum capacity of the switching or transformer gear in that circuit) of the line to carry the power safely or a security of supply constraint that limits the amount of power carried below its physical limitations in order to maintain an n-1 security rating (this is a measure of the ability to provide redundancy for the system and represents the ability to reroute the supply on that line through another line in the event of a failure of 1 component of that line).

There are also important differences in ownership and financial responsibility. The Grid is owned and operated by Transpower, and any new lines for connecting new generation that is added are paid for by Transpower. On the other hand, any new lines for connection of new generation to a distribution network has to be paid for by the owner of the generation, and end users are financially responsible for any repair or replacement of their network connection upon their property (this can be a significant cost for rural customers). This has a significant impact on financial viability of generation when comparing grid connected versus network-connected options for new generation.

For transmission, the Canterbury Regional

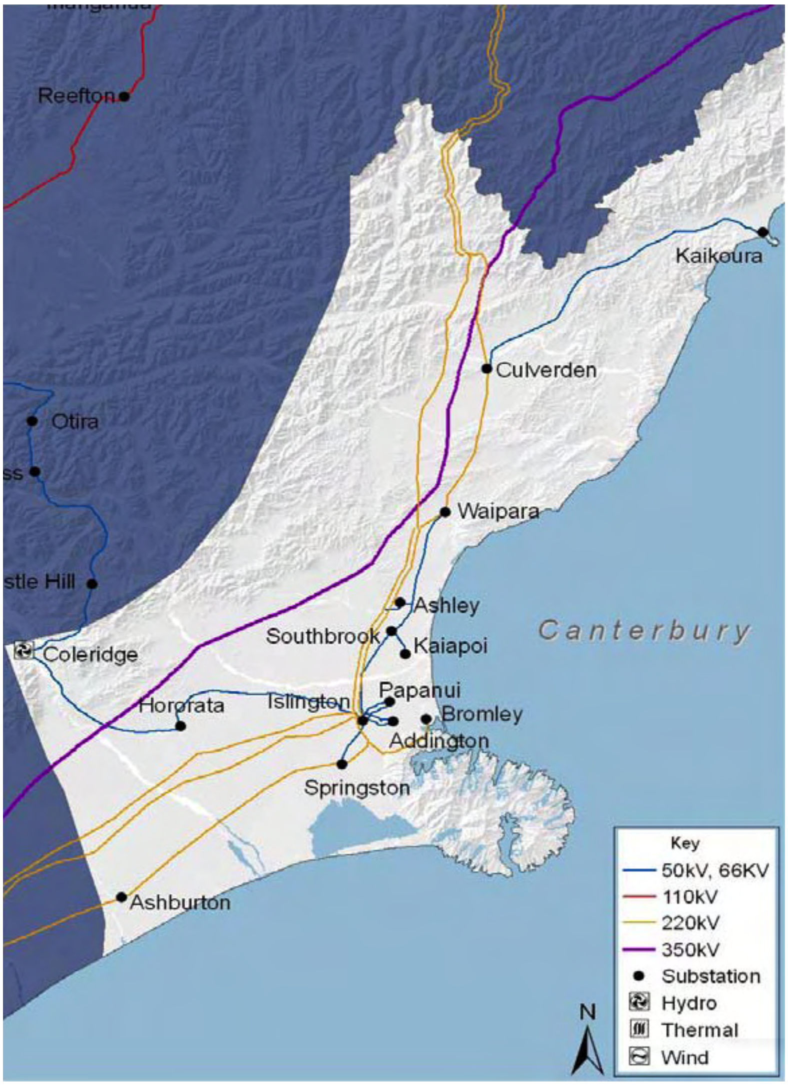



*Figure 4-1: Canterbury Region (www.gridnewzealand.co.nz/f41,2256/2256_canterbury-regional-plan.pdf)*

Council area is divided into Canterbury and South Canterbury (See figures 4.1 and 4.4).

### 4.1.1 Transmission - Canterbury Region.

**Canterbury Demand**

Figure 4.2 shows the forecast 10-year peak demand (after diversity[91]) for the Canterbury region compared to the forecast used for the 2007 APR. The forecast is based on the Electricity Commission's (the Commission) prudent demand forecasts (from its website, August 2007) and represents a 10% probability of exceedance.

**Future Canterbury Transmission Configurations**

Figure 4.3 shows the possible configuration of Canterbury transmission in 2018 with new assets shown in red.

### 4.1.2 Transmission – South Canterbury Region

**South Canterbury Demand**

Figure 4.5 shows the forecast 10-year peak demand (after diversity) for the South Canterbury region compared with the forecast used for the 2007 APR. The forecast is based on the Electricity Commission's (the Commission) prudent demand forecasts (from its website, August 2007) and represents a 10% probability of exceedance.

**Future South Canterbury Transmission Configurations**

Figure 4.6 shows the possible configuration of South Canterbury transmission in 2018. New assets are shown in red.

### 4.1.3 Generation Connections

There are no issues connecting generation at existing power stations within the Waitaki Valley at 220 kV. The primary purpose of the four 220 kV circuits going north towards Christchurch is to supply load. Connecting too much generation to any of these circuits could overload it and reduce the amount of load that can be supplied. The maximum generation limit varies with the point of connection and circuit. The generation is maximised when it is connected close to the Waitaki Valley and approximately equals the circuit rating.

The maximum generation limit is zero for the worst-case location and circuit, and 400-700 MW for the best circuit and location.

[91] The after diversity maximum demand (ADMD) for the region will be less than the sum of the individual grid exit point peak demands as it takes into account the fact that the peak demand does not occur simultaneously at all the grid exit points in the region.

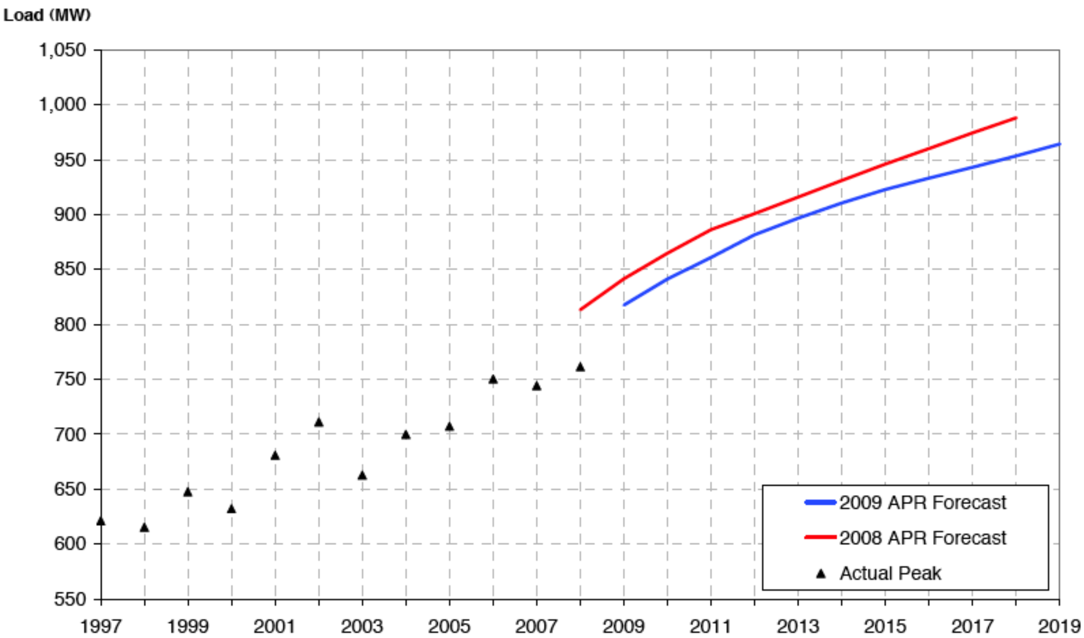



*Figure 4.2: Canterbury Region After Diversity Peak Demand Forecast*

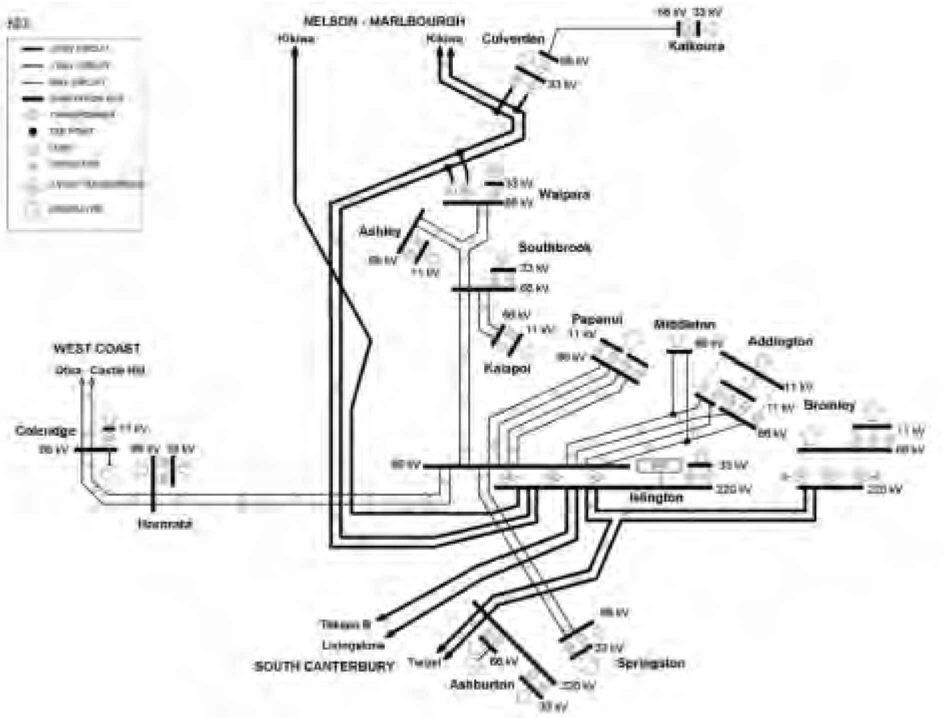


*Figure 4.3: Canterbury Transmission Configuration in 2018*
*(www.gridnewzealand.co.nz/f41,2256/2256_canterbury-regional-plan.pdf)*

There is limited opportunity to connect new generation to the 110 kV Tekapo A–Albury–Timaru circuit because of the existing generation at Tekapo A and the Opuha generation embedded at Albury, unless the circuit is upgraded. The other 110 kV circuits could have generation connected up to or slightly greater than the circuit rating. http://www.gridnewzealand.co.nz/f41,2259/2259_south-canterbury-regional-plan.pdf

### 4.1.4 Grid Development Strategy (GDS)

#### 4.1.4.1 Transmission 2040

- The GDS sets the direction for Transpower's transmission investment for the next 30-40 years.
- The current GDS is now over five years old, and no longer reflects the latest information such as technology advances, demand/generation trends or the Government's New Zealand Energy Strategy.
- Transpower has been inviting input from key stakeholders on the formation of the next GDS – to be known as 'Transmission 2040'. The 'Transmission 2040' process is likely to take about 18 months, culminating in a final strategy in about 2010.
- 2040 has been chosen as a snapshot year, with the planning assumptions actually running to about 2050.
- Four future scenarios have been developed to test sensitivity issues and the robustness of energy supply development plans. These are outlined in Section 1.2.

  http://www.gridnz.co.nz/f40,2951691/2951691_T2040_Overview.pdf

**Upper South Island future transmission investment.** In April 2008, Transpower released its approach to future transmission investment to secure long term supply to the upper South Island. That approach is to continue with investments currently underway, and plan for commissioning of a new Static Var Compensator (SVC) at Islington by 2017. An SVC will help support voltage and increase capacity of the existing network in the upper South Island.

Since 2005, Transpower has extensively consulted with interested parties on the need, assumptions and options for reinforcing supply to Christchurch and further north. From this consultation, a number of short-listed investment options were developed to test under the Grid Investment Test (GIT) – a test which all Transpower investments must pass.

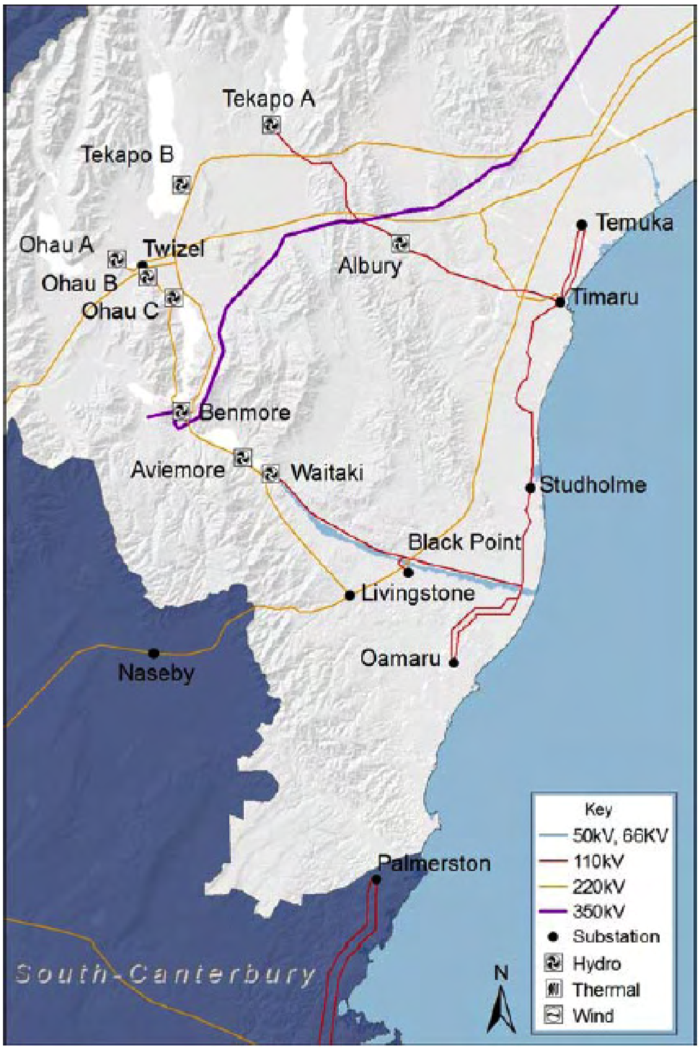



*Figure 4.4: South Canterbury Region*
*(www.gridnewzealand.co.nz/f41,2259/2259_south-canterbury-regional-plan.pdf)*

Transpower's General Manager Grid Investment Tim George said that during the consultation process, some of the planning assumptions were amended including the demand forecast and generation scenarios. The demand forecast in particular is critical in determining the timing for new investment.

"The results from our assessment under the GIT show that the most appropriate and cost-effective option for meeting the upper South Island's electricity needs in the long term is to install an additional SVC at Islington by 2017. Following this, either reconductoring of existing lines or building a new line could be considered; however this is not likely to be needed until around 2030."

"On this basis, Transpower does not consider it needs to submit a grid upgrade proposal to the Electricity Commission for either investment at this stage. However, we are acutely aware that demand forecasts can change over time, and being prudent, we will continue to monitor and consider additional options to provide more capacity – including bussing at Geraldine, and/or reconductoring one of the 220 kV lines into Christchurch. These could be implemented should actual demand increase faster than forecast."

Transpower was investing around $64 million in the upper South Island to help ensure reliability of electricity supply up to 2017. Substation improvements at Ashburton (due for commissioning in May 2008) will help balance load between circuits supplying Christchurch and further north, while additional reactive support at Christchurch and Kikiwa (for

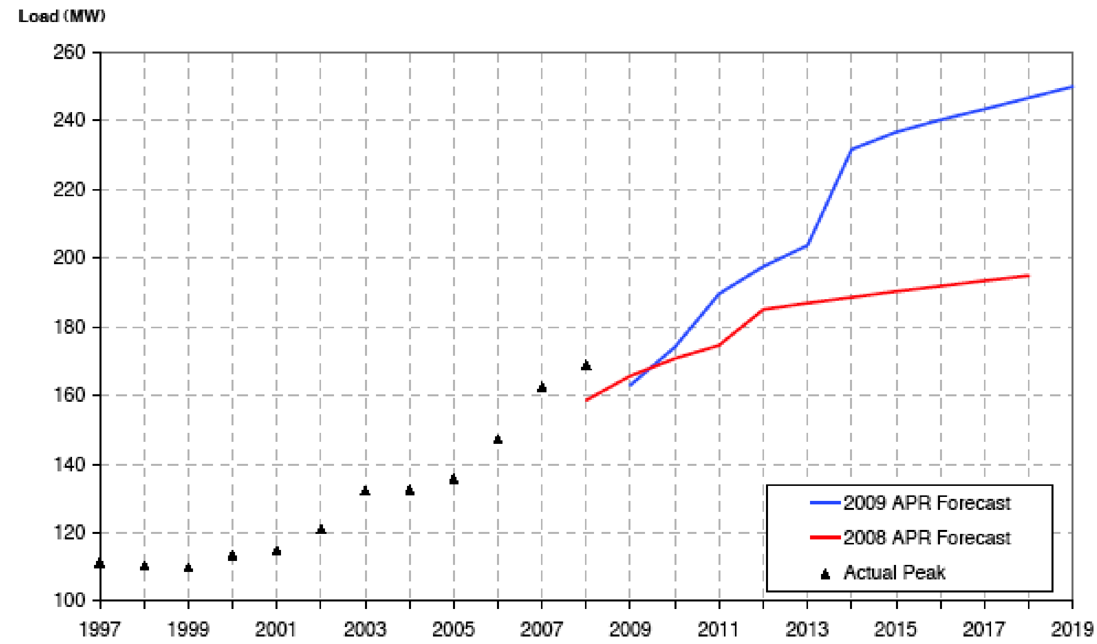



*Figure 4.5: South Canterbury Region After Diversity Peak Demand Forecast*

completion by 2009) will help support voltage in the region. Finally, Transpower is also investigating a refurbishment and upgrade of some existing assets at its Islington substation.

Demand side participation initiatives can help to defer transmission investment for 1-2 years which is another useful tool should a new investment be needed earlier than forecast. http://www.gridnewzealand.co.nz/n1533.html

**Enhancement of 220 kV Transmission Capacity between the Waitaki Valley and Christchurch:** Transpower has committed to enhancing the

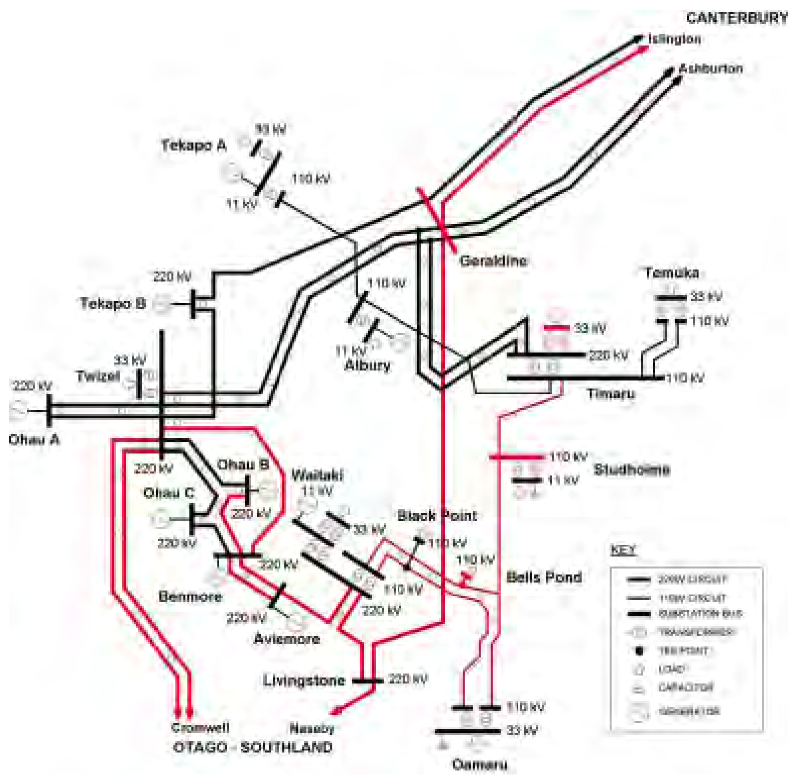



*Figure 14.6: South Canterbury Transmission Configuration in 2018*

transmission capacity between the Waitaki Valley and Christchurch.  This is a short-term solution and is expected to relieve the existing voltage stability issues north of the Waitaki Valley until approximately 2012. This is a committed investment project and has been approved by the Electricity Commission. (www.gridnewzealand.co.nz/n254.html)

**HVDC Pole 1 Replacement:** Transpower has proposed replacing Pole 1 of the HVDC link with a new pole by 2012. The new pole will be a state of the art thyristor valve unit and will increase the capacity of the overall HVDC link to 1000 MW from 2012, and 1200 MW from 2014.  Transpower anticipates that a new pole would provide sufficient capacity to ensure diversity of generation in the North and South Islands for the foreseeable future. This is a committed economic investment project.

http://www.gridnewzealand.co.nz/n278.html, http://www.gridnewzealand.co.nz/n283.html

**South Island unlikely to face cuts after $500m-plus grid upgrade:** Transpower reports more than $500 million of upgrading work on the southern grid in recent years.  South Island consumers had a 10 to 15-year buffer before they might experience grid problems like those in Auckland in February 2009. After 10 to 15 years, a major new lines programme would be on the cards.  *[Source: The Press 06 February 2009]*

#### 4.1.4.2 Electricity Commission's Statement of Opportunities

The EC is required to publish a SOO for transmission and transmission alternatives at least every two years. The SOO is to enable the identification of potential opportunities for efficient management of the grid, including investment in upgrades and transmission alternatives. In preparing the SOO, the Rules require the Commission to aim to meet the reasonable requirements of Transpower, investors in generation, other participants, end-use customers and those interested in evaluating transmission alternatives, and to reflect good electricity industry practice.

A key component of the Grid Planning Assumptions (GPA) is the Commission's electricity demand forecast which sets out the Commission's view on demand forecasts for the New Zealand electricity market. A key component of the GPA is the generation scenarios. The GPA is required to contain (among other things) 'a reasonable range of credible future, high-level generation scenarios'. Those developed for the 2008 report are:

- **Sustainable Path** - New Zealand embarks on a path of sustainable electricity development and sector emissions reduction
- **South Island Surplus** - renewable development proceeds at a slightly more moderate pace, with all existing gas-fired power stations remaining in operation until after 2030, though taking a more mid-order role as gas prices increase.
- **Medium Renewables** – a 'middle-of-the-road' scenario. Renewables are developed in both islands, with North Island geothermal development playing an important role.
- **Demand-side Participation** – demand-side participation becomes a more important feature of the market, driven by a desire from consumers of all types to become more fully involved.
- **High Gas Discovery** - major new indigenous gas discoveries keep gas prices low to 2030 and beyond.

These scenarios have been designed to encompass the range of uncertainty, rather than to provide a central forecast of investments. Although each scenario is intended to be a plausible view of the future, none represents the EC's view of a 'most likely' future scenario. In the context of the NZES, a key output statistic is the projected proportion of electricity that would be produced by renewable generation. Renewable generation fuels are deemed to include hydro, geothermal, wind, biomass, and marine, but not gas, coal or diesel. The exception is that coal or gas with carbon sequestration is considered to be renewable (because the greenhouse emissions would be relatively low).

The five scenarios vary in the extent of renewable generation as follows.

- Sustainable Path is 89 percent renewable by 2025.
- South Island Surplus is about 82 percent

renewable by 2025, with a bias towards South Island wind and hydro.

- Medium Renewables is about 77 percent renewable by 2025, with more generation located in the North Island.
- Demand-side Participation is about 69 percent renewable by 2025, with extensive demand-side involvement and high electric vehicle uptake.
- High Gas Discovery is approximately 69 percent renewable by 2025, with low gas prices due to indigenous gas finds.

### 4.1.5 Distribution - Canterbury Region.

There are five network companies in the Canterbury Region: MainPower, Orion, Electricity Ashburton, Alpine Energy, and Network Waitaki (see Figure 4.7). Most networks within the Canterbury and South Canterbury region are experiencing annual energy (GWh) growth rates between 2 and 3% and peak demand growth rates of between 1% and 2%. Orion undertakes a lot of work on peak shifting its load, resulting in its peak demand growth rate being at the lower end (1.3% averaged over 20 years).

Future load projection is a difficult task and is based on a complex multivariate environment. A careful and rigorous approach must be taken to developing future load projections based on historical trends, available information and estimates on future changes. Forecasts of maximum demand on the sub-transmission system are usually derived from internal modelling work.

It is important to assess the future load as accurately as possible since network investment is required before the load arrives, not after. Incorrectly assessed, the absence of load can leave expensive assets under-utilised. Future demand also comes in the form of security requirements that require additional or larger assets so that the network is more fault-tolerant.

The amount spent on any network is influenced by existing and forecast customer demand for electricity and the number of new customer connections to the network. Other significant demands on capital include:

- meeting safety and environmental compliance requirements
- meeting and maintaining security of supply standard
- meeting shareholder desires e.g. place existing overhead wires underground.

The growth rate in overall maximum network system demand (measured in megawatts) traditionally drives capital investment. Maximum demand is strongly influenced in the short-term by climatic variations (specifically the severity of our winter conditions). In the medium-term it is influenced by growth factors such as underlying population trends, growth in the commercial/industrial sector, and changes in rural land use.

Maximum demand is the major driver for network investment. This measure is very volatile and varies substantially in Canterbury depending on the vagaries of winter weather. For example Orion's Network maximum demand for the year ending 31 March 2007 was 632MW, up 40MW on the 2006 year; but only up 30MW on the 2002 year.

Before investing capital in a network, consideration can be given to the following:

- uneconomic customer connections
- 'demand side management' options
- 'distributed generation' options.

#### 4.1.5.1 MainPower

In its Statement of Corporate Intent 2008-2009, MainPower states that it will establish, operate and own renewable electricity generation in order for the region to become 75% self sufficient in meeting the energy needs of the region, and in addition will establish and operate a successful electricity retailing business.

(www.mainpower.co.nz/index.cfm/1,157,0,42,html) (http://www.mainpower.co.nz/index.cfm/3,146,280/sci-2008-2009-web.pdf)

MainPower's region is still one of the fastest growing in New Zealand and during the last ten years, growth in terms of electricity supplied to the region has increased by approximately 60%. MainPower's growth profile is not expected to change significantly, although the promotion of its energy efficiency and conservation strategy will have some impact. Actual growth during recent years and anticipated growth is presented in Figure 4.8.

**4.1.5.2 Orion New Zealand Limited**

Orion owns and operates the electricity network in central Canterbury between the Waimakariri and Rakaia Rivers, and from the Canterbury coast to Arthur's Pass. The network covers 8,000 square kilometres of diverse geography, including Christchurch city, Banks Peninsula, farming communities and high country.

Trends suggest a medium-term demand growth rate of 1-2% per annum (see Figure 4.9).

In the short-term Environment Canterbury's Clean Air Plan is driving higher demand growth (at 2% per annum), as the plan encourages customers to install electric heat pumps. The annual peak demand growth is expected to fall to 1% towards the end of the 10 year period covered by our Asset Management Plan (AMP).

See chart on p16 Asset Management Plan

Peak demand growth – expected winter peak demand on the total network will grow by an average of 1.3% per annum over the next 10 years, while summer peak demand on our rural network will grow by around 4% per annum.

Load duration - Maximum demand on the network sets the network capacity needed, but generally maximum demand only happens for very short periods. Whatever can be done is done to manage load to lessen maximum demand. For example, we routinely manage load by using 'ripple control' to automatically turn household electric hot water cylinders off. We aim to turn cylinders off for short periods only, to prevent any noticeable effects on customers' hot water supply. Turning off the cylinders reduces the congestion on our network.

The load is also managed indirectly through pricing incentives that reward retailers' customers who reduce the amount of electricity they use during our high priced 'peak period'. A 'ripple signal' is provided to tell customers that

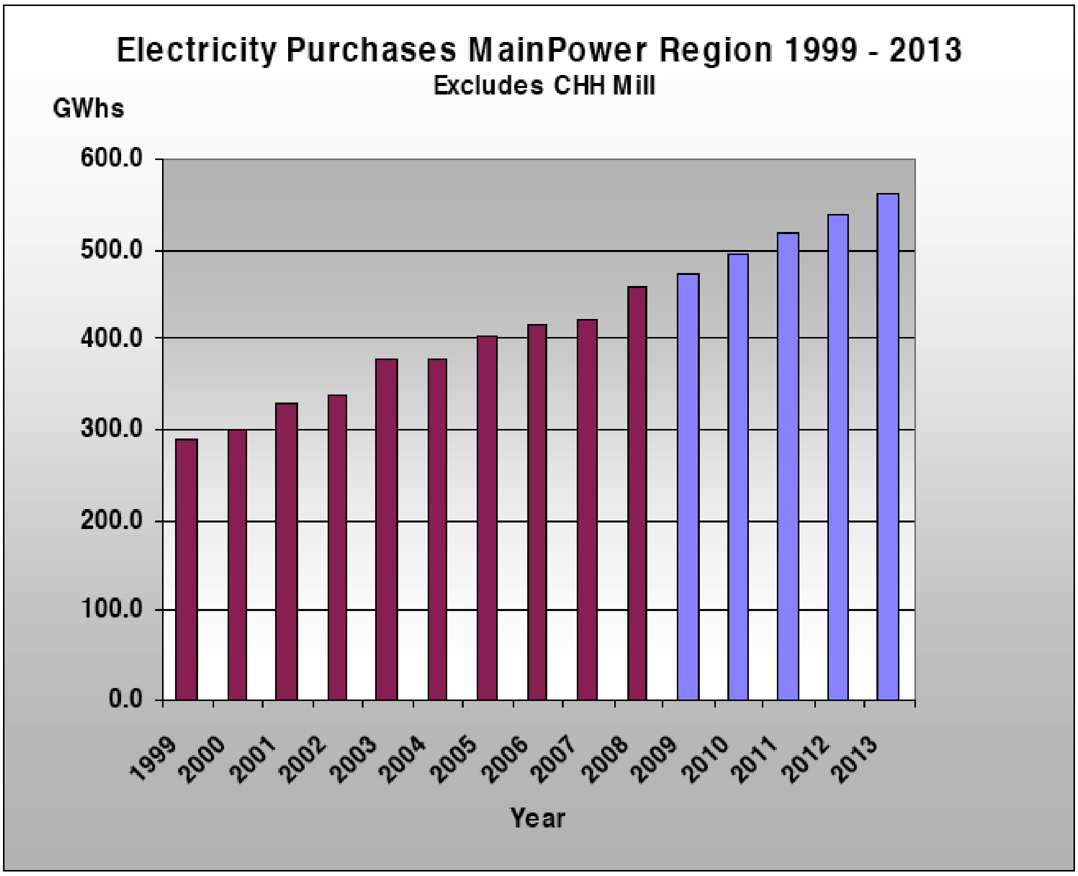



*Figure 4.8: Electricity Purchases MainPower Region 1999 - 2013 - excludes CHH Mill (www.mainpower.co.nz/index.cfm/3,147,279/mp_-annual_review.pdf)*

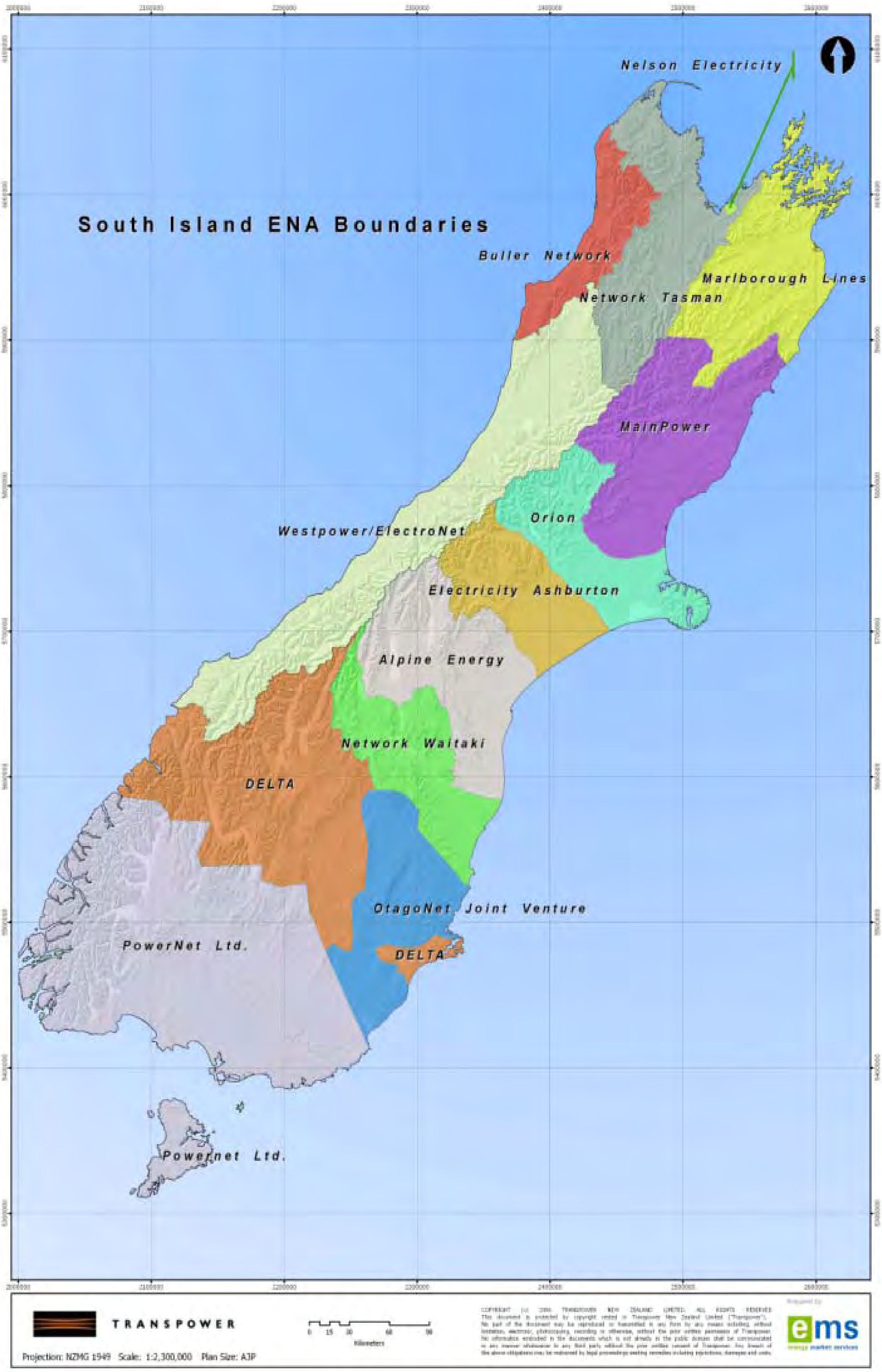



*Figure 4.7: South Island network company boundaries*
*(http://www.transpower.co.nz/f1010,109256/109256_lines-company-boundaries-south-island.pdf )*

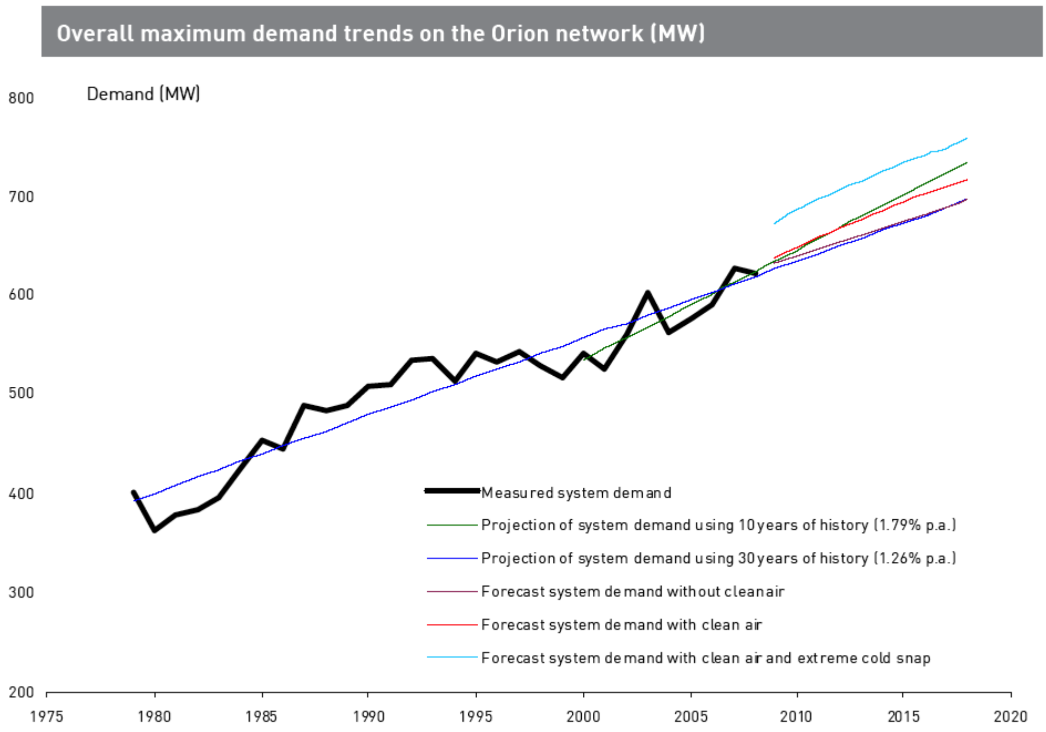



*figure 4.9: Orion New Zealand Ltd demand growth (www.oriongroup.co.nz/downloads/AMPsummary.pdf)*

it is a peak period so that they can reduce their load and reduce their charges. This arrangement is more useful for larger business connections which have special half-hour interval metering that records the reduced loading level during the peak period.

A load duration curve shows the amount of time a load exceeds a given value. In the year ending March 2007, load exceeded 623 MW for only 18 half hours and the highest net demand was about 628 MW. In the 2002 winter, if 'peaking generation' of 30 MW had operated for only four hours on our network, our urban network maximum demand would have reduced by about 30 MW.

Peaking generation could help to delay the need to increase the capacity of Transpower's network. This generation would usually operate for only a few hours over the largest peak demand times to avoid Transpower network constraints. In unusually prolonged cold conditions, longer hours of operation could be needed.

Control of winter maximum demand depends heavily on suitable price signals and customer response to price signals. To create and maintain appropriate price signals, it is vital that electricity retailers continue to support demand side management initiatives. Night rate tariffs are particularly important, as is load control via 'ripple receivers'.

The network maximum demand including exports from distributed generation for the year ending 31 March 2008 was 623 MW.

http://www.oriongroup.co.nz/downloads/AMPsummary.pdf

#### 4.1.5.3 Electricity Ashburton

Boundaries are the Rakaia River to the north and the Rangitata River to the south and from the sea to the main divide. Land use intensification including dairying, vegetable and small seed production has increased the district's need for irrigation water. Electricity capacity has doubled in the last ten years primarily driven by increased use of irrigation pumping. http://www.electricityashburton.co.nz/Company_Profile.html

Note: The data below is from Asset Management Plan 2006-7 http://www.electricityashburton.co.nz/Disclosure/AMP2007-08.pdf and is dated 31 August 2007.

The 2008 is indicated to be available from 29 August 2008.

There are two hydro generating stations embedded in the network. Montalto is a 1.6 MW station and Highbank is a 26 MW station.

Future Demand: Dramatic load growth has occurred in the Mid-Canterbury region over the last decade. The summer maximum demand has doubled since 1995. This has in turn driven very significant capital development on the Electricity Ashburton network.

Load Forecasting: Forecasts of maximum demand on the sub-transmission system have been derived from internal modelling work. Two forecasts have been derived. The first forecast is based on estimating the future load likely to occur on each zone substation. Separate summer and winter demands are estimated for the next ten years.

Extrapolating a moving four-year average growth linear regression line into the future for ten years has developed the second forecast. This method of projection has the advantage of incorporating unknown future load (load that cannot be estimated because it arrives as a step increase out of the blue) since it incorporates past "surprise" load.

The two models are divergent. The statistical projection cannot account for the likely downturn in irrigation load growth caused by water extraction restrictions. On the other hand, the individual load estimation reflects that downturn but does not account for unknown future load. It is of course likely that the truth lies somewhere between these two bounds. Assuming that to be so, the summer system maximum demand will probably exceed 137 MW by 2017 but is unlikely to exceed 164 MW. http://www.electricityashburton.co.nz/Disclosure/AMP2007-08.pdf

**Distributed Generation:** A public statement by Trustpower has said that they intended to use some irrigation race drops to generate electricity into the Electricity Ashburton network. These generators could have some impact on the summer maximum demand as they operate only when irrigation water is flowing (which tends to be when electrically driven water pumps are also operating). Few details have been provided about their plans but Electricity Ashburton look forward to working towards a mutually beneficial solution. Electricity Ashburton are also investigating the viability of some small hydro generation opportunities in conjunction with a proposed irrigation development. The development is still in its planning stages and will rely on other parties to commit before it becomes reality. Future plans will identify any firm proposals. There have been no proposals for connection of non-hydro forms of distributed generation to the Electricity Ashburton network that would affect the predicted maximum demand. There are some other small scale distributed run-of-the-river hydro generation opportunities that are being discussed and in one case pursued, but their collective output accounts for only two or three typical irrigation pumps and in drought years they are unlikely to be generating because of water restrictions on river offtakes.

**Projects:** One specific project has been identified for the plan period. A small (200 kW) induction generator is going to be used to provide energy from a large irrigation race drop that is presently wasted. The connection to the Electricity Ashburton network has been kept as simple as possible and as this is the first of this type of connection the likely operational characteristics are still being resolved. The consumer also wishes to be able to motor the induction machine to power some mechanical pumps that would otherwise be driven from the hydraulic turbine. This has created some deliberation (now resolved) on how the various capacity charges would be allocated but at this stage the consumer's remaining issues relate to the metering facilities required by the retailers.

Electricity Ashburton have become involved in a local irrigation scheme proposal that may offer some hydro generation as a by-product. The scheme would be situated on the Rakaia River near Highbank power station and two 1.3 MW generators could be installed. It has yet to be determined how the network connection arrangements would be handled but the generators would inject onto the 66 kV network. As the irrigation scheme project advances, additional detail on generation prospects will be included in future plans.

Trustpower have stated their intention to harness hydraulic drops in the Mid-Canterbury irrigation races to generate a total of about 6 MW spread over five or six locations. There are no firm details on these proposals but Electricity Ashburton look forward to working towards a mutually beneficial solution that this opportunity has presented.

### 4.1.5.4 Alpine Energy

Alpine Energy Ltd owns and operates the electricity distribution network in South Canterbury, New Zealand. The network has a replacement value of some $150 million, and connects 27,680 customers throughout the region with the six local Transpower points of supply. The Company jointly owns an asset management company and its subsidiary contracting company which provide a wide range of network and electrical services, and has investments in the Opuha Dam and Rockgas Timaru.

Alpine Energy based in Timaru services down to Glenavy on the north side of the Waitaki River and the Mackenzie Basin including Twizel. Therefore it also covers parts of multiple districts (see Figure 4.10). Alpine has mix of consumer trust, port company, and council ownership.

**Issues arising from estimated demand**

The significant issues arising from the estimated increases in demand are:

- Reinforcement of capacity and security at GXP level will involve large assets replacement with pass through transmission costs to customers.
- Increasing air-con load likely to over-lap peak periods
- Requirement to maintain ripple control services to ensure peak demand control is available to maximise load curtailment at peak times.
- These load increases will be inductive rather than resistive.

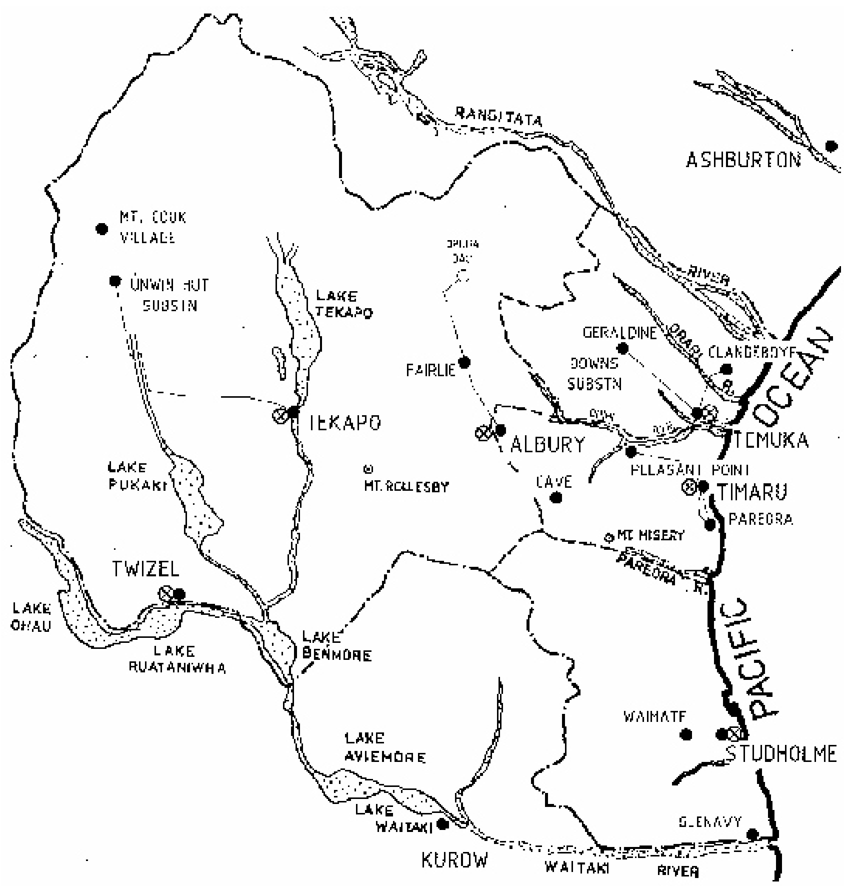



*Figure 4.10: Alpine supply area (www.alpineenergy.co.nz/AMP2009.pdf, page 255)*

- Potential to develop demand side management incentive for irrigators to curtail irrigation load through peak demand times.
- Twizel and Tekapo tourisim development will create winter load peaks.

**Non-electrical constraints**

Electricity networks are not only constrained electrically but also by the environment within which they are constructed.

Part of AEL's network is built within a coastal marine environment. This environment is hostile to most components used in an electricity network and is the principal driver of any accelerated maintenance programmes required to maintain service to consumers. Where possible, equipment designed for this environment is used. An example is the use of 22 kV insulators that fit on the same pin as the equivalent 11 kV insulators – this extends the life between failure due to salt and dust contamination and improves service to consumers for very little additional cost.

Proposed changes to utility access to road corridors by road controlling authorities has meant some rebuild projects along state highways have not proceeded. The new requirement of pole positions being 9m from the road edge would result in lines being constructed in private land with associated easement negotiations and costs.

This subject has now been escalated to a national level where the interests of all parties are being balanced and likely to result in utility access being restored. With a large amount of AEL's backbone network built along the dominant state Highway traffic routes there was a considerable risk of not gaining approval from the road controlling authority to replace works at end-of-life back as an overhead asset within the road, causing significant additional cost.

Resources remain a constraint on undertaking planned work. Growth in South Canterbury has focused efforts on capital investment in building new network assets to meet customer needs. This has meant that some maintenance work has been carefully prioritised with the most urgent maintenance being completed while minor maintenance is deferred pending available resources. External resources are also stretched with work on their local networks. Attracting external resources to work remotely attracts a premium which needs to be balanced against the value gained from immediate completion of the work or rescheduling the work to occur at a more affordable price. Hence Capex and Opex programs must remain flexible to advance when customer needs are suddenly unveiled or delayed when constraints in completing projects make it unviable to complete within the budget year and should be deferred.

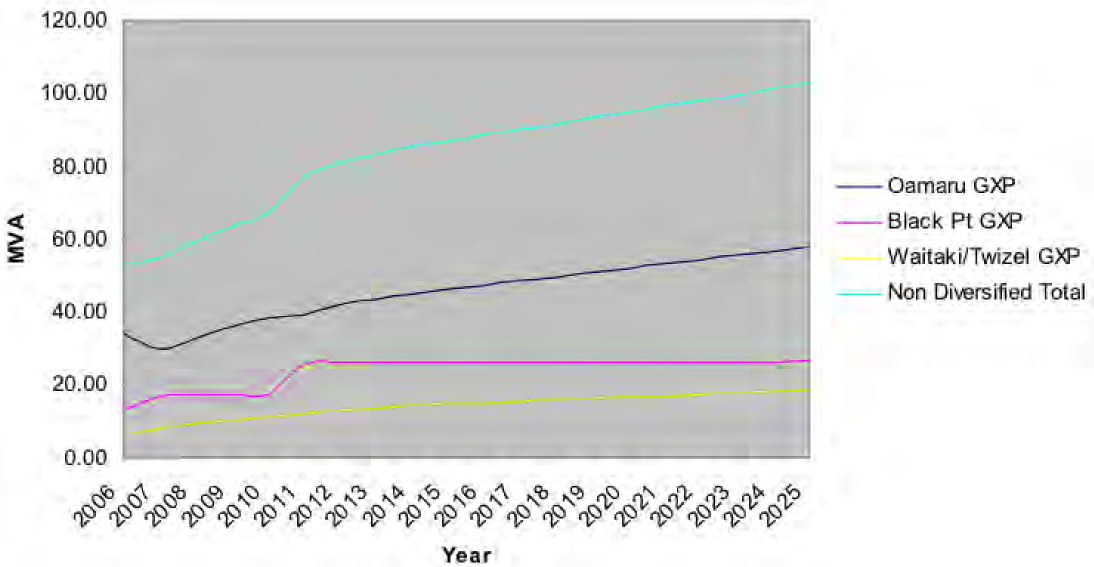



*Figure 4.11: Projected maximum demands Network Waitaki*

Access to private land is becoming more difficult in areas where land owners may not receive any direct benefit from the new works. There is now a substantial cost and lead time to negotiate land access agreements and formal electricity easement agreements which affect the timing of establishing new works. http://www.alpineenergy.co.nz/amp2007.pdf

#### 4.1.5.5 Network Waitaki

Network Waitaki, located in Oamaru, services from Shag Pt to the Waitaki River and up to the top of Lake Ohau. It also services the Hakataramea Valley and the north bank of the Waitaki River down as far as Stonewall which are in the Waimate District. Network Waitaki is not only divided by different territorial authorities but also two Regional councils; Otago Regional Council and ECan. Network Waitaki is a 100% consumer trust owned company.

Projected maximum demands are shown in Figure 4.11.

For the purposes of planning these forecasts are of little value other than to signal that NWL is expecting continued and strengthening high growth. Forecasts are sensitive with regard to major developments which are not influenced by NWL or its planning. Example – 17 MW for proposed cement works.

(www.networkwaitaki.co.nz/
Asset_Management_Plan_July_2007.pdf p50)

The primary distribution voltage of all three line companies is 11kV. Both OtagoNet and Network Waitaki have 33kV sub-transmission backbones to their networks.

Alpine takes supply from Transpower at 11kV in the Waimate/Studholme area. This is becoming increasingly more difficult and costly to support the more intensive loads associated with dairy development. The township of Waimate and the Dairy Factory at Studholme have security issues with the n-level GXP at Studholme.

These voltage standards are legacies of historic development. Otago has a lower population density and therefore greater distances and remoteness from the transmission system to deal with. Timaru was originally a council owned MED with good transmission support to service large industrial users.

Some rural networks, with high irrigation loads, have found it necessary to move to a 66kV sub-transmission and 22kV distribution voltage standard. However in this area irrigation water is abstracted from rivers rather than being lifted from wells and is therefore less energy intensive. Significant parts of the distribution networks (up to one third of route km) are single phase.

User-pays pricing makes medium to large load developments uneconomic in these areas. An issue with the region being served by more than one line company is that the interconnections between networks are very limited. The Waitaki River for example forms a natural boundary between the networks of North Otago and South Canterbury. Alpine Energy has difficulty supporting load at Ikawai, whereas network Waitaki faces challenges at Clarksville. Both these areas are at the end of long rural spur lines with no options for security or subtransmission support. These areas however are seeing no less development than other parts of these networks. Service is limited as result of historical line company franchise and the misfortune of being located at the boundary.

#### *4.1.5.6 Distribution Issues*

The specific issues faced by all line companies are:

- Increasing network capacity and density to match land use intensification.
- Extending more sub-transmission support further out into the network.
- Elevating security provisions and service performance to meet the requirements of new users and higher loads.
- Increasing interconnection and robustness into network configuration.
- Ensuring that networks are capable of connecting new and larger than traditional industrial loads.
- Competing for access and obtaining options to build new infrastructure.
- Meeting development costs via fair pricing principles that don't impede progress. This is a requirement of consumer ownership of line companies. NWL, for example, is charged by its shareholder with delivering benefit to their consumers both in terms of

low pricing and support of economic development.

In conclusion the national power supply is orientated and operated to servicing larger population centres as a priority over local interest. Local power users receive inferior service yet contribute towards the cost servicing of their competitors. By contrast, in terms of economic efficiency, local users, being closer to generation resources, should enjoy beneficial location signals in their energy and transmission pricing.

The region would arguably be more competitive, better serviced, facing a lower price path, and be more attractive for economic development, if it:

- Maintained a stakeholding in any new generation or obtained a stakeholding in existing generation up to 100% of local consumption.
- Developed its own transmission/ subtransmission system.
- Coordinated the development strategies of its local distribution lines companies.

It should be noted that there are pricing controls on line companies that present a hurdle to them investing in transmission. They are required to return all transmission-cost savings back to consumers, which can eliminate the business case for investment. Whereas, they can pass through any Transpower charges without any consideration of the cost and efficiency. Establishing a regional transmission company could overcome this issue.

There are also regulatory limitations on line company ownership of generation and energy trading. A local generation and retailing company could overcome this hurdle.

**Electricity Consumption Profile**

Trends in electricity consumption are displaying the following characteristics:

- A shift towards summer peaking driven by land use intensification. Peaky demand profiles create opportunity to utilise offpeak capacity at minimal cost. This requires applications that turn load off during peak periods rather just peak limiting. Energy storage is therefore of higher value as a demand side management tool. Previously demand management sought to level demand and maximise load factor. Transmission pricing methodology no longer signals this objective. For typical patterns of daily energy use, see Figure 4.12.
- Traditional seasonal loads are becoming

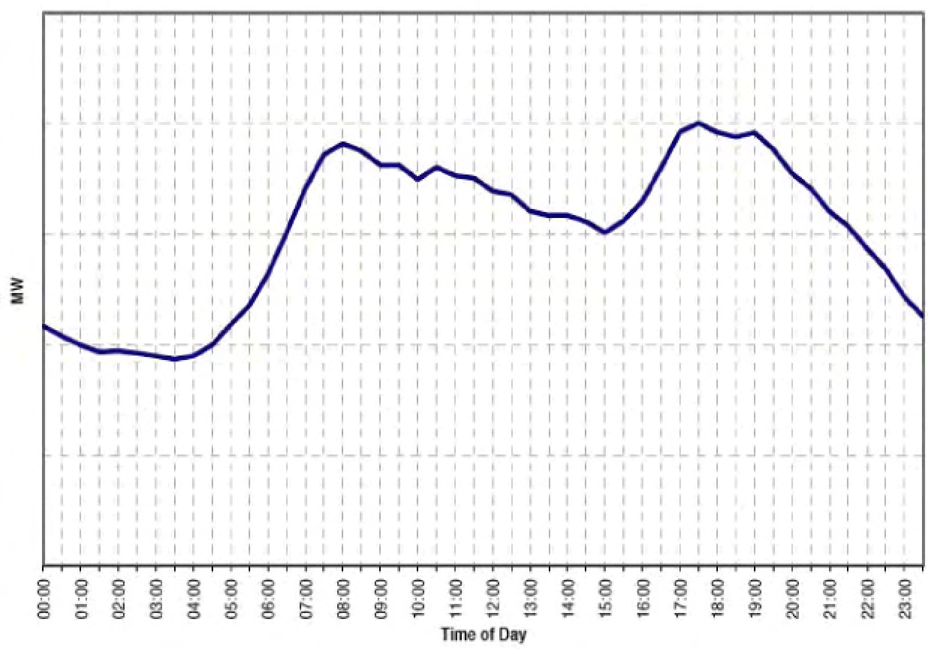



*Figure 4.12: Typical pattern of daily energy use (Source: TPNZ Annual Plan 2008)*

longer as industry operates double shifts and targets more diverse markets. System peaking can now occur in the shoulder seasons when the freezing works is operating, dairying is still in production and irrigation is operating because of dry conditions.

- Base load is showing a significant lift as production is increasing and consumers are shifting to on-demand convenience appliances such as heat pumps. Domestic efficiency incentives to date have resulted in increased electricity consumption.
- Holiday making is clearly evident in some feeder load profiles and often coincident with system peaks.

## 4.2 Gas Supply Chain

Liquefied petroleum gas (LPG) is the only available gaseous fuel (typically a combination of propane and butane) in the South Island. There are no storage facilities at Lyttelton. LPG is sent via pipeline over the Port Hills to storage sites near the Woolston liquid fuels depot.

Rockgas' and Ongas' storage facilities are adjacent. Annual consumption in the region in 2004 was estimated to have been around 50,000 tonnes. This suggests that available storage was around 10-11 days' consumption in 2004. With rapidly increasing consumption, this coverage is decreasing rapidly in the absence of some capacity expansion. This (maximum) consumption coverage stands in contrast to the amount of coverage for other petroleum fuels. (CRESP_WS02 Report December 2006)

**Marine Distribution of Compressed Natural Gas (CNG)**

CNG shipping into New Zealand could support New Zealand's natural gas markets on a small scale or as an interim measure, avoiding the commitment of high capital costs for LNG importation infrastructure.

## 4.3. Liquids Supply Chain

This section provides a summary of the liquid fuels supply chain as it applies to the Canterbury region. That is, the supply chains described here include both transport and non-transport fuel supply (and includes LPG). Four companies dominate petroleum distribution and retailing; BP, Mobil, Shell and Caltex. These companies have interests in the Marsden Point oil refinery and between them they own most of the bulk storage facilities and many of the country's petrol stations. Petroleum fuels are predominantly shipped to Lyttleton Port from Marsden Point with smaller amounts being shipped to Timaru. There are tank farms located at both of these ports that comprise the main bulk storage facilities. From Lyttleton Port, products destined for the Christchurch market are transported through a pipeline, owned by Mobil, over the Port Hills to Woolston. Product destined for elsewhere within the region or the West Coast are moved from the port by road transport.

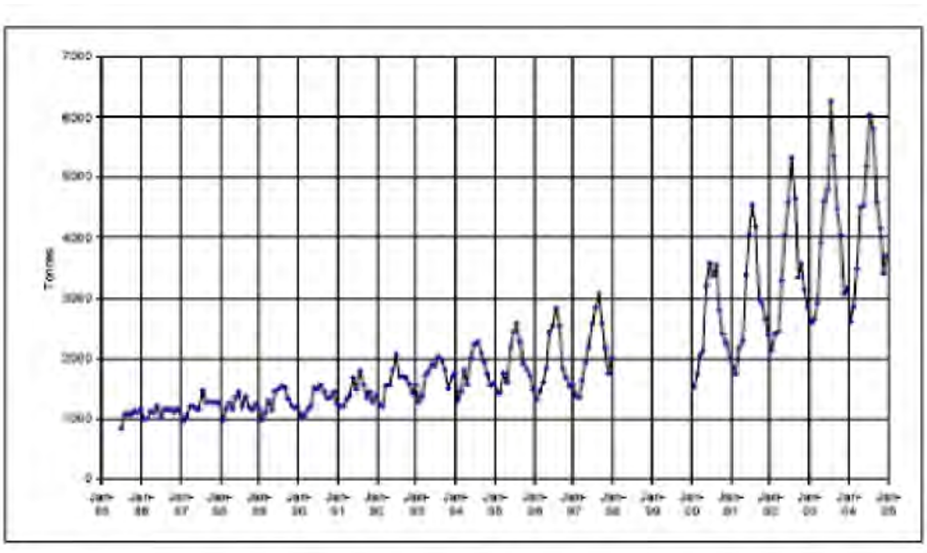



*Figure 4.13: (Maximum) Bulk Storage Capacities in the Canterbury Region [17]*

Bulk storage capacities in the Canterbury region up to 2005 are shown in Figure 4.13.

Bulk storage facilities are capable of holding around 49.5 days of regional consumption in 2004 [55]. Timaru Port has about around a quarter of the region's storage capacity and thus has much more capacity relative to local consumption than does the Christchurch region.

## 4.4 Solids Supply Chain

Coal transported into the Canterbury region, for either local consumption or export, arrives by rail.

As shown in Table 4.1, exports of coal have increased strongly in recent years, aided in no small part by buoyant world commodity markets, significantly caused by the strong economic growth in China.

Sometimes nearly 100% of New Zealand's coal exports are sent through Port Lyttelton. This underlies the importance of the West Coast-Lyttelton rail link for transporting coal from the West Coast for export, making it likely the most important export 'lifeline' in the country. Similarly, Port Lyttelton is pivotal to the coal export industry, especially as alternatives are not available in the short term. Coal exports now account for over 25% of Port Lyttelton's throughput volume. The Fonterra diary plant at Clandeboye is the Canterbury region's major industrial user of coal. The coal is railed in from Ohai.

**Report in The Press 27 Feb 2009:** Lyttelton Port coal volumes rose 12.2% compared with the same period last year, although full year volumes are expected to be slightly lower than last year, with an expected reduction from Solid Energy New Zealand West Coast operations. In other trades fishing, logs exports and motor vehicle imports all recorded reductions. Both fuel and dry bulk imports achieved relatively similar volumes compared with the same period last year, and full year volumes should be in line with the previous year.

| | 2008 | 2007 | Percentage Change | Comment |
|---|---|---|---|---|
| Total Container Volumes (TEUs) | 250,657 | 228,284 | 9.8% | Both import and export trades reported good growth, with dairy exports recording the most significant increase (18.8%). |
| Total Containers through the Container Terminal | 225,335 | 199,400 | 13% | |
| Coal Exports (tonnes) | 2,246,342 | 2,170,773 | 3.5% | Steady production led to target volumes being achieved. |
| Bulk Fuel (tonnes) | 1,104,692 | 1,077,921 | 2.5% | Fuel rose slightly in the year. |
| Motor Vehicles (units) | 39,691 | 30,600 | 29.7% | This increase can be attributed to higher than average imports in advance of changing vehicle regulations on 1 February 2008. |
| Logs (tonnes) | 143,627 | 148,362 | (3.2%) | Logs are down slightly, impacted by soft export demand. |
| Dry Bulk Imports (tonnes) | 590,477 | 569,624 | 3.7% | The main increase was in cement. |
| Ship Visits (number) | 1214 | 1,193 | 1.8% | The number of car ships rose slightly. |

*Table 4.1: Lyttelton Port Company traffic volumes 2007/2008 (Source: Lyttelton Port Company's 2008 Annual Report)*

# 5 DEMAND REDUCTION

## Canterbury Region Energy Efficiency and Conservation Techniques

> *The choice is simple, sustainable development, unsustainable development or no development at all.'*
>
> Sandy Halliday, Build Green (1990)

The arguments for using energy more efficiently are compelling. Such programmes increase efficiency, reduce energy costs, improve air quality and conserve natural resources and allow longer lead times for the development of new electricity generating facilities. The publication *"Energy Efficiency – A guide to Current & Emerging Technologies"* was produced by the Centre for Advanced Engineering in two volumes in 1996. This continues to be an excellent reference. The Energy Efficiency and Conservation Act 2000 defines energy efficiency as "a change to energy use that results in an increase in net benefits per unit of energy".

The ongoing development of technology and increasing energy prices mean that new, more efficient technologies constantly become available. This means that there is generally potential to improve the efficiency with which we use energy to support various aspects of our lifestyles and industrial activities. Achieving that potential requires the replacement of existing technologies at the end of their life with more efficient technologies. It is often also cost efficient to replace existing technologies ahead of their expected lifetime, or before they are worn out completely. Also, refit options can be available.

'Potentials' are typically quantified at three levels: Technical potential, economic potential and market potential. Realising potentials is constrained by behavioural, technological, economic and takeback constraints. Only recently have the complex interaction of factors that alter energy efficiency potentials started to be assessed. Takeback: There are real limitations to potentials in that typically new energy technologies provide both service or productivity improvements as well as energy savings. [NZ Energy Information Handbook, 2008]

The benefits of demand-side driven energy efficiency are available to business and domestic consumers, as well as the providers of electricity infrastructure, and the environment:

- From the customer's perspective, saving electricity reduces power bills that leave more money in their pockets. This clearly provides some incentive for adopting energy efficiency measures, provided they are well understood and meet cost-benefit expectations.
- From the electricity infrastructure provider's perspective, energy efficiency also has the potential to impact positively on the bottom line, because it offers the opportunity of reducing the costs of installing new infrastructure. This is because reduction in consumer demand through energy efficiency measures (such as better insulation of houses, or the installation of solar hot water heating) reduces pressure on lines companies to upgrade infrastructure within towns and cities to meet the demands of population and housing growth. And in rural areas, the impact of the spread of lifestyle blocks on the need to upgrade lines capacity can be offset by greater uptake of energy efficiency measures.
- The generation of electricity has environmental effects – whether this is from thermal, wind, geothermal or hydro sources. Hence promoting energy efficiency provides a win-win-win solution for the environment, the consumer and the electricity provider. [Draft Waikato Regional Energy Strategy, 2008]

The built environment presents us with a major challenge. The construction, fit-out, operation and ultimate demolition of buildings is a huge factor in human impact on the environment both directly (through material and energy consumption and the consequent pollution and waste) and indirectly (through the pressures on often inefficient infrastructure). The built environment also has a crucial impact on the physical and economic health and well-being of individuals, communities and organisations. A good building is a delight and will enhance a community or organisation, enhance our ability to learn or increase our productivity. A poor building will do the opposite.

Sustainable development is now stated policy of local, national and international governments, and much industry and commerce. There appears at last to be a growing commitment to reverse unsustainable trends in development. To meet the challenge we have to enhance quality of life for all by designing healthy buildings and environments fit for individuals and communities now and in the future.

There is already a significant amount of information available to all professions on how to design buildings that are attentive to the needs of sustainable construction, but most practice still falls short of applying even the most easily applicable principles in most projects. A book Sustainable Construction by Sandy Halliday (2008) aims to summarise the existing sources of best practice guidance on the design of sustainable and built environments.

In industrialised countries, on average almost half of the overall energy consumption is apportioned to the energy supply to buildings, that is to heat, cool and ventilate them and supply them with electricity. The rational application and efficient use of energy worldwide have become primary political and social aims. A rapid and thorough rethink is required by those who play a substantial role in the construction and planning process, namely the architects, building owners and regulatory authorities. This also means, amongst other things, that professional training, models of financing, standard specifications and laws must be adapted to this new objective. These adjustments are already underway.

The need is for system solutions or more accurately the combination of modern heating technology with renewable sources of energy. Only the mutually beneficial application of efficient technologies and renewable sources of energy will solve today's problems and those of the future. http://ish.messefrankfurt.com/frankfurt/en/fakten_energie_gebaeude_klimatechnik.html

## 5.1 Residential Sector

For New Zealand houses, estimates indicate:

- 18% (250,000) of houses have no ceiling insulation at all, or insulation in less than 50% of the roof area
- 60% of houses (900,000) have ceiling insulation of inadequate thickness
- 700,000 houses have no, or little, wall insulation
- 740,000 houses with suspended floors have no under-floor insulation, but 650,000 could be insulated

For Canterbury houses, based on population (census) the above housing number estimates could be divided by eight.

http://www.beaconpathway.co.nz/Portals/5/Final_Dispatch_Insulation_single.pdf

Table 5.1, based on the HEEP research (BRANZ) provides the estimates for Canterbury (Christchurch) of the annual gross energy in kWh for the fuels (and the two major end-uses) which were monitored in a significant number of houses.

| | Hot Water | | Space Heating | | Total (including other services) | |
|---|---|---|---|---|---|---|
| **Fuel** | **ChCh** | **NZ** | **ChCh** | **NZ** | **ChCh** | **NZ** |
| Electricity | 2710 | 2440 | 950 | 920 | 8710 | 7800 |
| Gas | 140 | 660 | 90 | 520 | 230 | 1180 |
| LPG | | | 320 | 240 | 320 | 240 |
| Solid fuel | 110 | 150 | 1640 | 2150 | 1750 | 2310 |
| All fuels | 2960 | 3250 | 3000 | 3830 | 11010 | 11530 |

*Table: 5.1: Average annual energy use (kWh) per house by fuel*

These are averages over all New Zealand houses – not the fuel use that would be found in a house with that fuel and that end –use. Note that fuel oil is not separately included due to the small HEEP sample size. [NZ Energy Information Handbook]

**Suburban building sites.** Solar-effective houses cannot be placed on unsuitable suburban sites. Their effectiveness relies on the main (long) facade facing within 30∫ of north. The reason is simple - the sun has an inexorable daily transit across the sky which cannot be changed and if advantage is to be taken of free solar gain then acceptance of, and working from this fundamental fact, is essential. As far as energy savings are concerned it is irrational and uneconomic to continue to plan housing sites that are unsuitable for solar-effective houses.

### 5.1.1 General Building Design

- The Home Energy Rating Scheme (http://www.eeca.govt.nz/residential/home-energy-rating-scheme/indexnew.html ) allows potential home buyers to have a quantitative estimate of a building's energy efficiency in design. It is likely that in the future the Councils will hold (and possibly record on Land Information Memoranda) additional information such as the energy efficiency rating data under the Home Energy Rating Scheme (HERS).
- The Institution of Professional Engineers New Zealand met with Peter Neilson, Chief Executive of the New Zealand Business Council for Sustainable Development (NZBCSD), who was seeking support for its initiative for a programme to upgrade the existing housing stock valued at $580 billion. The cost of these upgrades is in the order of $22 billion, so if this is to happen there has to be an incentive. Peter and the NZBCSD believe that a home rating system that is a co-led initiative by government and industry could take advantage of an industry downturn to improve the existing housing stock to the benefit of New Zealanders' health and welfare. The scheme essentially recommends that New Zealanders obtain star ratings for their homes, which would provide evidence that the home achieves various degrees of performance. For the scheme to gain momentum, NZBCSD believe that it would need to become a requirement that the seller or landlord of houses sold or rented declares whether or not they have a rating and if so, what it is. Peter believed that this "warrant of fitness check" – which he valued at less than $500 – would be a service that engineers might be able to offer in addition to work that they might already be asked to do by the homeowner. www.nzbcsd.org.nz/housing/content.asp?id=446 (March 2009)
- City Council's guides. Guides promoting sustainable building design and building site selection and planning are available from the City Council. They address important issues such as passive solar design and optimum orientation for solar access, topography and landscaping, thermal insulation, sustainable use of building materials and other energy related topics. See: *The Waitakere City Council Sustainable Home Guidelines*: http://www.waitakere.govt.nz/AbtCit/ec/bldsus/shsummary.asp
- Christchurch City Council's Energy Show Home offers ideas for economic improvements to homes for greater energy efficiency. The *Energy Awareness Week* lecture series and study tours (March/April 2009). www.ccc.govt.nz/energyawareness http://www.ccc.govt.nz/Environment/EnergyEfficiencyShowHome/
- Other schemes include: Environment Canterbury's CleanHeat Project: http://www.cleanheat.org.nz/christchurch.html , Warm My Home Ltd.: http://www.warmmyhome.co.nz/ , Smarter Homes: http://www.smarterhomes.co.nz/ , http://www.righthouse.co.nz/ ,Sustainable Homes winner: www.futurehomesnz.co.nz

### 5.1.2 Insulation

ew Zealand houses are considered amongst the worst in the OCED, with a lack of insulation meaning many are cold, wet and draughty. Estimates suggest that the Canterbury region has more than 100,000 homes that have been built prior to the requirement to have any basic insulation. Building code requirements for the minimum standard of thermal insulation for new houses has been increased many times over the period 1978 to 2008. Upgrading older houses is an opportunity and a challenge.

- Improved space heating efficiency. Space heating and cooling is estimated at about

23PJ nationally, or 35% of the energy used in homes. In Canterbury, the average annual gross energy is estimated at 3830 kWh/house (Table 5.1)

- Use of alternative (natural, recycled) materials such as wool, recycled newspaper reduces energy investment in production.
- Community Energy Action (CEA) offers comprehensive information on the degree to which homes should be insulated: http://www.cea.co.nz/how-will-i-know-if-my-house-needs-more-insulation/
- Long term durability and performance of insulation is critically dependent on installation quality.
- The predomination of light timber framed houses in New Zealand imposes limitations on insulation. Continuing industry use of 100mm studs practically limits wall insulation to a high density product of about R3.0 which, with normal amounts of wall framing, would provide a maximum wall insulation value of R2.2/R2.3. This poses a significant 'break point' around increasing wall R-value beyond about R2.2, and cost-effectiveness considerations need to factor in more than just the cost of a higher R-value product.
- Wall insulation effectiveness is further reduced by the thermal bridging created by additional framing associated with doors, windows and wall junctions. A wall with 25% window area could reduce the R-value of insulation by at least 20%. Construction techniques are available for reducing the thermal bridging effects of framing but they are not commonly used in New Zealand. http://www.beaconpathway.co.nz/Portals/5/Final_Dispatch_Insulation_single.pdf
- New scheme to make Canterbury families healthy (December 2008). CEA is part of a major new home insulation and heating programme called "Warm Families". This project brings together a range of partners to improve the health and wellness of low-income Canterbury families by turning their damp, cold homes into energy efficient, warm, dry and healthy homes. Project partners include the Energy Efficiency Conservation Authority (a major funder), local lines companies Orion and MainPower, power retailer Meridian Energy, the Canterbury District Health Board, and Partnership Health Canterbury.
- Downstream cost savings due to improved occupant health: Hon. Gerry Brownlee "One of the things the government is focusing on at the moment is household insulation. Around 860,000 houses in New Zealand have no insulation, or are under insulated. 235,000 of these homes are occupied by people on low incomes. Research from the Wellington School of Medicine shows that for every dollar spent on insulating cold houses, there is a two dollar return in energy and health savings. One night in hospital costs the same as insulating a whole house. I have tasked the Ministry of Economic Development and EECA with designing a plan to significantly boost the number of home insulation retrofits occurring in private homes.

  Investing in home insulation doesn't just make sense from a health and productivity point of view, it's also the right type of infrastructure boost our economy needs just to keep jobs through the downturn. I'll be making announcements about the government's intentions for more home insulations later." (24 Feb 2009) http://www.beehive.govt.nz/speech/unlocking+new+zealand039s+energy+and+resources+potential.
- Cost effectiveness: Higher-than-Code levels of insulation will be justifiable for many new houses in Canterbury. Another factor to consider is that if the highest, cost-effective standards of insulation are not installed at the outset, for some building components the cost of rectifying via retrofitting is likely to be several times higher. There is a need for guidance – either through HERS or by updating the 'better' and 'best' levels of insulation previously provided through *SNZ PAS 4244:2003*.

### 5.1.3 Thermal mass

reduces heating requirement after natural heating periods. Heat is stored within the living space without excess temperatures and significantly improves comfort, reduces over-heating. Good design should mean that air cooling is not required in Canterbury homes. Note that the Code allows a reduced minimum thermal insulation for 'solid wall' constructions. However to be effective thermal mass needs to be insulated on the exterior side of the thermal mass.

The effectiveness of thermal mass increases significantly with the increase in insulation. Floor slab insulation is most effective if the perimeter foundations are thermally broken from the slab as the primary heat loss is direct to outside air rather than through the ground. While the thermal break on its own only adds R0.2-0.3 it then makes it worthwhile to put insulation under the whole slab whereas, without the thermal break, whole slab insulation may be no better than just edge insulation. Effective details for insulating slab floors have only recently been developed and further work is required to assist their uptake. http://www.beaconpathway.co.nz/Portals/5/Final_Dispatch_Insulation_single.pdf The value of using a significant amount of thermal mass should be considered in all buildings.

- Achieved using large amount of solid materials such as concrete (vs. e.g. weatherboard construction) especially, concrete slab floors. Solid timber walls can also be effective.
- Inbuilt heat exchanging pipes in concrete slabs for heat transfer
- Increasing solar uptake by use of an adjoining 'glasshouse'.
- Phase change materials in wall linings offer a potential alternative to heavy thermal mass.

### 5.1.4 Glazing

Heat loss through glazing is significant because the R-value is very small. Even with double glazing the R-value is still relatively small compared with the minimum values required for other areas of a building.

- Orientation and size of windows to limit/increase solar energy gain
- Double glazing to reduce heat losses. Now required for new houses. Heat loss through the window frames is also significant.
- Photoactive coatings/tinting to limit sunlight, reduce space cooling requirement.
- Shading (part of building) of north facing windows to cut out summer sun but allow winter sun to penetrate deep into the house.
- Care needed with sky-lighting and potential overheating.

### 5.1.5 Ventilation

While ventilation is important, from an energy efficiency standpoint, it should be designed and controlled. Research suggests that inadvertent air change can account for more than half the heat loss through a building envelope. Current research into ventilation of walls is focusing on finding out the actual leakage path rather than simply the air change rate. The target for infiltration is down to 0.5 air change/h for a well sealed house.

- Reduce air infiltration to limit energy losses – improve door and window fittings
- Smart venting – open during daytime on hot days but close in the evening to preserve heating.
- Dehumidification can alter the balance between adequate space heating and ventilation, improving comfort levels without compromising energy efficiency (accepting that dehumidifiers are inherently energy consuming devices)
- Directly vent kitchen, bathrooms & laundry to remove internal moisture.
- Seal off moisture from the ground under a suspended timber floor – this reduces the moisture penetrating into the house and timbers, and reduces energy needed for heating. See Figure 5.1.

http://www.beaconpathway.co.nz/Portals/5/Final_Report_TE210_Thermal_Insulation_in_NZ.pdf

### 5.1.6 Active Space heating

Average annual gross energy 3000 kWh/house (Table 5.1) Cooling needs should be avoided by good design using thermal mass and night ventilation.

- Improve appliance electrical, mechanical efficiency through maintenance, product development. Air-to-air heat pumps continue to improve in their performance.
- Smart switching, thermostatic control to reduce overheating. Programme lower night temperatures (16°C).
- Increased use of cheap materials (i.e. wood) for space heating. Wood fires may be considered to be $CO_2$ neutral.
- Replace low efficiency heaters (e.g. open fires) with more efficient devices (e.g. log burners, pellet fires). In Clean air zones

*Figure 5.1: Under-floor insulation and on-ground moisture barrier*

there are rules that apply between 1 April and 30 September each year. See also Section 3.6.3 Wetbacks – wood stove to heat water. For *Six Heating Options* see: http://www.mfe.govt.nz/publications/energy/warm-homes-heating-options-phase1-nov05/html/page4.html

- At the municipal level, incorporating centralized heating systems would be an excellent sink for low-grade heat from power stations/industry.
- Cycling hot water in radiators (hydronic heating) is easily controlled space heating.

**5.1.7 Hot water heating:** Average annual gross energy 2960 kWh/house (Table 5.1)

- Increase hot water heat pump usage vs. electric furnaces to improve efficiency
- Improve insulation around hot water cylinders
- Reduce stored hot water temperatures to reduce conductive heat losses (but keep temperatures above 55°C to prevent *legionella* growth.
- Reduce hot water cylinder size to load requirements.
- Solar hot water heating system – up to 75% efficient, although large capital cost outlay, and requires coupling to mains energy or gas. See Figure 5.2. It is estimated that Christchurch and Banks Peninsula have around 3,000 solar hot water heating systems (2006). This renewable energy source reduces the use of electricity and fossil fuels. Solar energy used directly for heating water or buildings is not counted as part of the energy supply.
- The Solar Industries Association (http://www.solarindustries.org.nz/) provides information for home owners on installing solar water heating systems
- Wood fuel burners combined with space heating – see section 3.6
- Low flow shower heads

**5.1.8 Lighting.** Average annual energy use for lighting in Canterbury (Christchurch survey) is 530 kWh/house (BRANZ)

- Delamping (or use of reflectors to minimize lighting losses).
- Replacing incandescent light bulbs with compact florescent bulbs (though require specific recycling scheme to deal with new bulbs). Local campaigns can also dovetail in with national campaigns. For example, the Electricity Commission launched a scheme aimed at getting one million energy

saving eco-lightbulbs in New Zealand homes. Working with Shell, Trustpower and Housing Corp, the promotional campaign has offered the opportunity to purchase five eco-bulbs for $10 at Shell service stations. Technology company Energy Mad says New Zealanders have already saved enough electricity by using eco bulbs to supply Christchurch's power needs for one year. In New Zealand by September 2008, 53 percent of all New Zealand houses have five or more eco bulbs.

- One recessed light fitting for every 5m² of ceiling reduces the effective thermal resistance of R2.5 insulation by approximately 10%. Different forms of recessed light fitting (CA rated or Fire Resistant) can greatly reduce these energy losses but are often not installed because they are more expensive. http://www.beaconpathway.co.nz/Portals/5/Final_Dispatch_Insulation_single.pdf
- Recent Government policy has reversed the proposed introduction of MEPS for lighting.

**5.1.9 Local generation**

See Figure 5.3.

- Incorporating solar photovoltaic panels into roofing and walls.
- Solar access rules to protect installations from future shading, particularly trees on neighbouring properties need to be developed.
- New housing needs to plan for future solar PV panels. Many roof designs are quite unsuitable.
- Small wind turbines – on roof tops.

**5.1.10 More efficient appliances** Average annual energy use in Canterbury (Christchurch survey) for refrigeration is 800 kWh/house and for all cooking is 990 kWh/house (BRANZ).

- EnergyStar is an internationally recognized labeling endorsement for energy efficiency
- EECA publish guidelines on the minimum energy performance standards (MEPS): for appliances (http://www.eeca.govt.nz/labelling-and-standards/meps.html) Example from Australia - the energy consumption of refrigerators and freezers has been in decline since 2004. In fact, from 1993 to 2006, the average energy use of these appliances has decreased by 40%. Once again, it has been stringent energy efficient programmes that have brought about this decline through both the energy labelling system and the introduction of MEPS.
- In January 2009 ISES (International Solar Energy Society) organised the first International Solar Food Processing Conference (ISFPC) 2009 in Indore, India. See Figure 5.4. http://www.ises.org/newsletters/ISES2009_1.pdf

*Figure 5.2: Example of solar hot water heating (Source: CCC)*

*Figure 5.3: Examples of local generation for a house (Source: Jeanette Fitzsimons)*
*http://beehive.govt.nz/sites/all/files/Energy%20Strategy%20JF%20slides.pdf*

*5.1.11 Energy management*

- Improved behaviour towards energy conservation – turning off appliances at walls when not in use, turning off lights. Running appliances represents approximately 20% of energy consumption - with almost 5% of energy used to run appliances in standby mode.
- Alternatively, automated switching of appliances and lighting
- Regular maintenance to reduce hot water leaks, insulation gaps, infiltration etc.
- Make use of reduced nighttime electricity prices (e.g. turning off water heating during the day, using night-store heaters)
- The introduction of Smart Metering will

*Figure 5.4: Various solar food processing and cooking technologies (Photo Source: Rolf Behringer)*

allow households to monitor their own energy consumption and

- EECA's EnergyWise website goes into detail on domestic energy efficiency strategies and management: http://www.energywise.govt.nz/

*5.1.12 Toolkit for local councils*

Beacon Pathway Limited (Beacon) is preparing a toolkit for local councils that will identify and develop best practice approaches to sustainable residential developments. http://www.beaconpathway.co.nz/Portals/5/Final_Report_PR201_Local_Council_Barriers_Incentives_Case_Studies.pdf

An important aspect of the toolkit will be best practice in terms of district plans and related regulatory tools under the Resource Management Act 1991 (RMA). To help develop the toolkit, a review of selected district plans has been undertaken. This review has highlighted that the issue of sustainable residential buildings is one that district plans are only just beginning to grapple with.

A recent report by Beacon *"PR 200: Local Council Sustainable Building Barriers and Incentives – Auckland City Case Study"* identified a number of barriers to sustainable building in relation to Auckland City Council's district plans and its code of practice. As part of the development of the toolkit, this report has looked at a wider range of district plans.

The analysis has identified the following common barriers:

- Traditional development controls (height, yard, height-in-relation-to-boundary, building coverage, etc) where there is no exemption or allowance for features such as rain water tanks, solar panels or small-scale energy generation.
- Solar orientation is often constrained by yard and height-in-relation-to-boundary rules which push buildings into the middle of lots so as to protect sunlight to adjoining properties. There is no requirement to orientate buildings on lots for sunlight.
- Low impact approaches to stormwater management are restricted to areas of particular environmental sensitivity, or where there are infrastructure constraints.
- Process issues were highlighted as a major barrier to the incorporation of sustainability features, with the costs, uncertainty and delays of getting consent for discretionary and non-complying activity consents (including the need for written approvals) generally deterring people from incorporating sustainable features.
- Codes of practice were similarly identified as a barrier, although Kapiti has illustrated a positive way of addressing alternative solutions.

Key methods identified for addressing potential barriers and encouraging sustainable features include:

- Objectives, policies and assessment criteria that recognise and provide for sustainability and enable the wider positive benefits to be taken into consideration through resource consent processes.
- Allowance within standards for features like rain tanks, but also providing exemptions where sustainable features are included.
- Non-regulatory methods such as guidelines or information that assists in designing development appropriately to reflect sustainability matters.
- Development controls that require sustainability features, such as requiring appropriate building orientation for solar gain and natural ventilation.

## 5.2 Commercial Sector

### 5.2.1 Building Design

- Incorporates most of the design and construction techniques covered in the residential section i.e. use of thermal mass, insulation, double glazing, natural lighting etc.
- Refurbishing and retrofitting older (less efficient) buildings offer the greatest short term improvement to efficiency.
- Reduction of the use of HVAC systems in favour of a degree of natural heating and ventilation will reduce energy use. Also providing a higher quality building envelope etc, reduces the capital required on HVAC.
- Recycling building materials and sourcing sustainably developed materials reduces overall energy investment

- Use of climate-adapting (U-shaped) or atrium, rather than climate-rejecting (block) design
- The *'Handbook of Energy Efficiency and Renewable Energy'* (Kreith and Goswami eds., 2007) contains extensive information on energy conservation schemes and alternative technologies for businesses.
- Development of "*Green Star*" ratings for commercial buildings. The New Zealand Green Building Council has developed a "*Green Star*" rating system for commercial buildings. The system will be an important benchmark tool for raising energy efficiency measures and thereby contributing towards energy sustainability.

### 5.2.2 Internal Power Generation

- Internal power generation using micro-turbines and fuel cells, combined with heat recovery ('cogeneration', 'Combined Heat and Power') and perhaps use of a condensing cycle for cooling ('tri-generation') offers >90% efficient use of energy

### 5.2.3 Lighting

- Using day-lighting in combination with holographic glazing, which directs lighting towards the ceiling increasing diffusion and reducing heat effects
- Replacing 38mm fluorescent tubes with 26mm tubes have short payback periods and increased energy efficiency (7-9%). However they require a higher kickstart voltage.
- Triphosphor tubes produce more lighting, potentially resulting in delamping with lower overall energy usage.
- High Intensity Discharge lamps (e.g. metal halide lamps) can be used at higher listing efficiencies than conventional fluorescent tubes.
- Replacing light diffusers can increase lighting in place of adding extra lamps.
- Clever bulb placement can reduce the amount of bulbs required for adequate lighting. Increased use of task lighting can increase the effect.
- "Solar flags" can, where appropriate, take over the function of an advertising medium. The "solar flags" consist of special semi-transparent, grey solar cells, which are embedded between slightly bent acrylic glass panes. The elements are luminous and at night they give off the energy generated and stored during the day by powering integrated light emitting diodes (LEDs).

### 5.2.4 Space Conditioning

- Increased heat exchanger sizing reduces the load on the compression and expansion motors.
- Other passive and alternative cooling methods exist.

### 5.2.5 Appliances

- Laptop computers are generally more energy efficient than desktop computers
- Use of server-networked slim-line or small-form-factor computers significantly reduce energy consumption and limit environmental controls to the much smaller space of the server room (cf. the entire office space using individual computers)
- Automated (and centralized) power management systems on computers reduce energy consumption significantly.
- Groups of refrigeration appliances should have their warmed air ducted externally from a cooled area of a building – otherwise the net result of these appliances is to heat the cooled area.

### 5.2.6 Energy Management

- EECA provides information and tailored energy management plans for small and large businesses: http://www.eecabusiness.govt.nz/emprove/
- Keeping records and close monitoring of energy use by space, building and fuel type is necessary to identify potential for determining priorities for changes to reduce energy use.

## 5.3 Industrial Sector

### 5.3.1 Distributed Generation (DG)

A plant producing its own electricity and using the heat/cooling cycles as a byproduct (co/tri-generation) are together more efficient than dedicated heat/cooling plant + mains electricity. Orion New Zealand Limited (Christchurch's electricity network owner and operator) is unique amongst electricity network companies in its approach and support of sustainable energy. It does this in a variety of ways, but particularly in its support of distributed generation (DG), which is electricity generated locally by diesel, wind, solar, gas power generators, or other means. Orion facilitates the connection of all such generators to the network to enable power to be exported by DG owners and paid for by Orion. Orion's pricing policy, in conjunction with comprehensive information and technical support, has made distributed generation at peak demand times financially viable and attractive to major public, commercial and industrial customers that already have standby generators at their facilities and plant.

This combined "Christchurch power plant" consists of around 100 diesel and gas generators able to generate 20 MW, at Orion's request, at peak load times. This practice improves reliability of power supply to the city, reduces overall electricity costs to Christchurch community (by deferring or even avoiding significant capital expenditure to upgrade transmission lines and local distribution network), and results in a better energy efficiency due to reduced transmission losses. It also encourages renewable energy options such as wind power generation and biogas co-generation projects in Orion's network area. [SESC, Sustainable Energy Strategy for Christchurch 2008-18]

### 5.3.2 Energy Integration (i.e. Pinch Technology)

- Capital costs (and operating overheads like maintenance) can be reduced by more efficient integration of heat exchangers within a large plant.
- Heat recovery from plant utilities is a significant free-energy opportunity. A wide array of heat recovery technologies are described in Part 8 of *"Energy Efficiency – A Guide to Current & Emerging Technologies"* published by CAE, 1996.

### 5.3.3 Use of non-energy intensive operations

- E.g. membrane separation processes cf. conventional evaporation or centrifugation processes

### 5.3.4 Use of pressurized hot water as an alternative to steam

### 5.3.5 Load balancing

Scheduling electrical energy intensive operations to non-peak load times. For large electricity users, charges are based on peak loads (kW) in the period (month) as well as the energy (kWh) used.

### 5.3.6 More efficient refrigeration cycles

- Scheduling specific equipment according to its efficiency at given loads
- Alternative refrigerants e.g. use of carbon dioxide as a supercritical refrigerant cf. conventional ammonia cycle allows greater heat transfer
- Variable-speed fans for where air is the heat transfer medium

### 5.3.7 More efficient evaporation processes

- Examples: Multiple-effect evaporation, Thermal vapour recompression, Mechanical vapour recompression (heat pumping)
- Allows heat recovery from evaporated water (or other fluid)

### 5.3.8 More efficient drying processes

- Better use of ultra-high temperature or low pressure cycles for (e.g.) kiln drying
- Low-temperature drying/dehumidification processes instead of freeze-drying

### 5.3.9 Alternative heating technologies

- E.g. Microwave and radio frequency (RF) heating, induction heating in metalworking industries, infrared heating

### 5.3.10 Controlled environment rooms to limit space conditioning requirements

- Limiting door openings (e.g. in cool stores) can limit heat ingress/egress, reducing energy expenditure

### 5.3.11 Alternative energy sources

- Biogas generated from process waste (extensively used at Christchurch

Wastewater Treatment Plant

- Use of woody biomass for heating fuel or syngas generation at timber product mills
- Use of solar thermal systems and photovoltaics on buildings with large sunlight exposure (e.g. warehouse roofs)
- E.g. Verkerks boiler conversion to run on waste tallow-based fuel rather than mineral diesel

### 5.3.12 Automatic control

("Smart-switching") of plant utilities to limit use to off-peak times

- E.g. air compressors, hot water heating

5.3.13 Improved plant maintenance

- E.g. air compressor leaks account for a significant amount of wasted energy
- Maintain records of plant hours of operation for future energy auditing.

## 5.4 Agricultural (Primary Production) Sector

### 5.4.1 Distributed Generation

- Large non-urbanised areas are ideal for installation of wind turbines and micro-hydro power generators.
- Waste streams such as effluent and poor quality produce are a local and free 'fuel' for energy production (both electricity production from biogas and diesel production from crops)
- Typical primary production occurs at a significant distance from generators, hence DG would limit losses from long power transmission distances
- Electricity supply to small-scale primary producers is becoming more insecure as line maintenance is not prioritized.
- Feed-in tariffs and arrangements for connections.

### 5.4.2 Reduction of the use of energy intensive agricultural products

- Urea requires a lot of energy to produce (363m≥/h natural gas per tonne). Combined with some biotechnological products (e.g. Donaghys 'LessN', gibberellic acid products), urea use can be limited for the same effect on pasture growth.

### 5.4.3 Use of alternative fuels or energy

(see comments on the Industrial Sector)

- Water in irrigation races – drop structures for direct pumping to irrigators at some distance from the water race, or electricity (DG)
- For off-grid properties, it can be more cost effective to install a small-wind turbine as part of a stand-alone system than to pay for a connection to the electricity network, which can cost between $20,000 and $25,000 per kilometer. (ECCA, 2008)

### 5.4.4 Plant maintenance and retrofitting

(including tractors). See CAE reports on *"Improving Dairy Shed Energy Efficiency"* (2008).

- Insulating milk plant, hot water cylinders and pipe work against heat and cooling losses
- Use of heat exchangers and heat pumps as alternatives to simple heaters or refrigerators
- Ensuring valves and pipe work don't leak; fans and filters are clean and well-maintained.
- Ensuring plant is not oversized for the application

Ice banks for milk cooling. Ice banks are sometimes used to provide the chilled water because they have the added advantage of providing a method of storing cooling energy for later use. They were sometimes used in the early days of mechanical refrigeration when low-powered refrigeration systems were unable to cool the milk quickly enough. By storing the cooling energy as ice, the refrigeration unit could operate at low power over a long period to provide the required cooling. It is understood that some of these ice banks are still in use in remote areas of New Zealand where electricity supply capacity is limited. For a similar reason, the BioGenCool system currently under development in Canterbury uses an icebank to spread the refrigeration load across the whole day and so provide a steady base load for an on-farm generator partly powered by biogas.

The use of ice banks (or chilled water storage tanks) on dairy farms to shift electrical load from periods of high demand to periods of low demand has also been suggested by many and adopted by some. While this may be of advantage to the owners and operators of the electricity supply network, the incentive provided by current electricity pricing is not sufficient to make this a common practice. Some equipment suppliers and energy advisers promote the use of thermal storage systems as a means of reducing electricity costs. An advantage of using a chilled water storage system to provide most of the milk cooling is the ability to re-charge the chilled water store at night when electricity prices are lowest.

http://www.southlandnz.com/Portals/0/Documents/Business/Regional%20Initiatives/Technical%20Report.pdf

### 5.4.5 Use of heat recovery from waste

- such as hot water washes, exhaust from chillers and vacuum pumps

### 5.4.6 Lighting

(see Residential section 5.1 above)

### 5.4.7 Reduction of transport energy investment

- On-farm concentration of milk would reduce the total load requiring transport to dairy processing plant, reducing diesel energy usage. Depends on energy and capital cost requirements for further on-farm processing.
- Dispersion of fertilizer and agrichemicals may hold energy-efficient alternatives (such as using ground vs aerial spraying or v/v)

### 5.4.8 Farm building design

(esp. intensive pig and poultry farming) requires air conditioning and lighting, which would be alleviated somewhat by adequate ventilation, insulation and natural lighting (see Residential section 5.1 above).

## 5.5 Transportation Sector

The National Energy Efficiency and Conservation Strategy (October 2007) has a transport action area that includes:

- Managing the demand for travel;
- more efficient transport modes;
- improving the efficiency of the transport fleet;
- developing and adopting renewable fuels.

The Canterbury Regional Land Transport Strategy 2008-2018 has no details on the energy issue of developing and adopting renewable fuels.

### 5.5.1 Alternative fuels and technology

- A widely expanding industry, due to increased awareness of global warming effects of transport fossil fuels and forthcoming 'peak oil'. Current front runners for fossil-fuel replacing technologies are plug-in electric vehicles (Lotus/Tesla Motors 'Tesla' Roadster), and hydrogen fuel cell vehicles (Honda 'FCX Clarity')
- Increased availability may lead to increased use of CNG and LPG-fuelled vehicles
- Petrol/Electric Hybrid engines have proximate energetic advantages, but these are dubious when considering the life-cycle analysis
- Hemi engines attempt to conserve fuel at low loads by turning off cylinders (Chrysler '300C', 2008 Honda 'Accord V6')
- New efficiency technologies make better use of waste heat to power onboard vehicle systems, and recover electrical energy using regenerative breaking

### 5.5.2 Hydrogen

The "hydrogen economy" has often been touted as the long-term replacement for an economy based on fossil fuels, with cars powered by hydrogen fuel cells being the transport component of this economy. However, there are many obstacles in the way of this vision becoming a reality. Hydrogen is an energy carrier rather than an energy source – in other words, energy from some other source must be used to make the hydrogen that powers the cars. Furthermore, fuel cell vehicles are not commercially available, and infrastructure to support their use would be difficult to implement in New Zealand. Hydrogen must rate as, at best, a long-term option only.

New Zealand does not have nuclear energy able to produce hydrogen with off peak electricity. Significant investment in clean coal technology would be needed to produce hydrogen from our lignites and therefore development of such a facility will depend where scale places it on the technology cost stack. A move to a hydrogen based economy will result in continued dependence on off shore energy and technology development and is therefore not an optimal strategy for NZ in the medium term. (http://www.sef.org.nz/papers/peak_oil_land_transport.pdf).

### 5.5.3 Electric Vehicles

See Figure 5.5.

By 2050, the government sees 60% of New Zealand's (non-heavy freight) vehicles will be electric - with those using fossil fuel dropping to just 2% of light vehicles on the roads. Substituting fossil fuels with electricity in the transport sector is considered a very likely scenario with the majority uncertainty being around how much substitution will take place and the timing.

For different vehicle types NIWA has estimated the cost of operation for 10 years including capital costs, fuel costs and a carbon cost of $50/ton. See Table 5.2 for a comparison of 10 year total operating costs of different vehicle types for the years 2009 and 2030. (http://www.celsias.com/article/coming-energyshift-update).

Lithium-ion cells are poised to take an increasing share of the auto battery market, just as electric drive seems set to begin a long, slow climb to become, at last, a serious power-train option. Even if electric vehicles gained a 60 per cent market share by 2040, they would use only 15 per cent of current power demand. Because most would be recharged overnight in off-peak periods, they would give generators confidence to build more variable-supply windfarms and may even help to reduce electricity tariffs.

A good strategy for NZ is for all-electric cars to have the option of PV panels at home for charging. Electric vehicles use much less energy. As an example the Solar Taxi www.Solartaxi.com is reporting 8kWh/100 km on its around the world journey (with a trailer). That is energy equivalent to 0.8 litres per 100 km in energy terms. One litre of petrol is approximately 10 kWh of energy. Electric motors are 80-95% efficient. Internal combustion engines in cars only achieve about 13-20% (average 17%) efficiency and so most of the energy never gets to turn the wheels. It is wasted as heat. The following are examples of electric cars that are expected to soon be seen more often on New Zealand roads:


*Figure 5.5: Mitsubishi MiEV Electric car*

- Hyundai has announced a projected sales base of 200 plus vehicles per annum. The cars for sale will be a fully electric, plug-in version of the Getz. As an electric car the Getz will have zero emissions. The Getz is a retro-fit electric car, meaning that the batteries and electric motor are fitted to the car after the petrol engine is taken out. This process will be undertaken in New Zealand. The electric Getz has a top speed of 120 km/h with a range of 120 km on a single charge with a fast charge extending the range for a day's running to approximately 200 km http://www.scoop.co.nz/stories/BU0809/S00534.htm
- Major car manufacturers are ramping up production of electric vehicles, with many set for commercial release within months. The challenge for New Zealand is to get cars in the face of overwhelming international demand, which has far exceeded supply of the vehicles. New Zealand's largely renewable electricity sources make it an attractive proposition for companies entering the electric car market. Meridian Energy has a deal with a Japanese car manufacturer to introduce a small fleet of electric vehicles for trial and promotion purposes.
- In the USA, Chrysler LLC announced that the Company and its ENVI organization have new production-intent, advanced electric-drive technology packaged in three different vehicles – one for each of its brands, Chrysler, Jeep® and Dodge. Chrysler will select one electric-drive model to be produced in 2010 for consumers in North American markets, and European markets after 2010. Additionally, approximately 100 Chrysler electric vehicles will be on the road in government, business, utility and Chrysler development fleets in 2009.
- Now on the road in Christchurch is a second-hand Chinese-made Pioneer EV. This three-wheel electric ute is classified as a motorcycle, not a car, with registration only about $100 a year. It costs about $1 a day to run and is powered by six 100-amp hour batteries, drawing 72 volts which is enough to drive about 25 km after a six-hour charge. With battery technology improving its range should expand. Top speed is 65 km/h. New cost is about $12,000, but the demo model cost $8000.
- One internationally renowned electric vehicle expert says New Zealand should look closer to home for its future fleet, and believes we could be mass-producing our own cars by 2015. Waikato University professor Mike Duke says small, two-person cars could be built here and sold for as little as $10,000 each. (http://www.stuff.co.nz/4690959a11.html)

"It is not clear that electric vehicles will provide either a technologically, or an economically viable solution, within the next two decades." Dick Stimpson, Arup Future Transportation. The EECA Biofuels & Electric Vehicles Conference, March 2009.

### 5.5.4 Hybrid electric buses

In Canterbury, Ashburton bus manufacturer Designline Ltd is producing hybrid electric buses, which are in use in Christchurch and Auckland, and have also been sold overseas. The buses, which fill a niche market for environmentally friendly, ultra-low emission passenger vehicles, generate electricity to charge batteries which run electric motors. The batteries are charged overnight, and the turbine system also recharges them when operating. In addition, energy from braking is used to charge the batteries. Designline started work on the hybrid electric vehicles a decade ago after realising there was a market which the company could fill internationally.

| Car type | 2009 costs | 2030 costs |
|---|---|---|
| Compression ICE | $39,800 | $48,600 |
| Spark ICE | $57,800 | $60,000 |
| Battery Electric vehicle | $57,100 | $27,400 |
| Hydrogen Fuel Cell vehicle | $203,900 | $27,800 |

*Table 5.2: Comparison of 10 year total operating costs of different vehicle types (see NIWA (2008): "New Zealand's EnergyScape". Presentation 16 July 2008 by Rilke de Vos. Available from: http://www.niwascience.co.nz/ncces/projects/energyscape)*

### 5.5.4 Improved load matching

(reducing vehicle size to necessity, not desire)

- Generally, smaller cars would be sufficient for the majority of transport currently conducted by larger individual private passenger vehicles

### 5.5.5 Alternative transport methods

- Walking school buses: The walking school bus is a group of children who walk to and from school supervised by adults. Like a real bus, it travels at a set time and children leave the bus at special stops situated close to where they live. As Auckland University research found; "While WSB (walking school bus) stakeholders (e.g parents, school managers, city travel planners, injury prevention specialists and health promoters) differ in their priorities, a consensus on the effectiveness of this intervention has emerged. The WSB is clearly working at a number of levels as its participants are walking." See Figure 5.6.
- Christchurch specifically has an ideal geography for cycling. See Fig 5.7. Considerable progress has been made over the last three years in New Zealand, in that most councils have now developed either walking or cycling strategies (or both). However, all but three councils need to develop, update or finalise walking or cycling strategies. http://www.ltsa.govt.nz/road-user-safety/walking-and-cycling/docs/walking-cycling-strategy-stocktake.pdf
- Changing to lower fuel usage per person-kilometre. An example is airline travel, which although known to be a highly energetic process, results in a fuel economy of 2 litres of gasoline equivalent/person-km, compared with a private car with two occupants averaging around 5 litres/p-km. Table 5.3 provides comparative data for the different transport modes. Rail travel is the most energy efficient on a passenger-km basis. Yet the most energy intensive modes, cars and domestic air travel comprise around 90% of both energy consumed and distance travelled.
- Table 5.4 offers comparative data for freight transport. Whilst road transport is not the most energy efficient mode for freight transport, it is, nevertheless, the dominant mode by which freight is moved.
- Coastal shipping: Sea Change is a government strategy setting out proposed actions to help industry and government transform the domestic sea freight sector so that it can play its part in the overall transportation system. The aim of Sea Change is for coastal shipping to make a major contribution in managing future freight growth. Total freight movements are expected to more than double by 2040, putting huge pressure on the transportation system. Shipping has a vital role to play in meeting this expected growth in freight movement, and is a key part of an integrated transport network. Sea Change is supported by government funding for investment in port facilities. [Waitaki Report]
- Canterbury Regional Land Transport Strategy 2008-2018 http://www.ecan.govt.nz/NR/rdonlyres/ACA80D93-C178-49EF-A49C-0CCD2145947A/0/RegionalLandTransportStrategy2008201825July2008.pdf

### 5.5.6 Demand management

- Reducing the need for transport via more energy-conscious town planning and improved access to alternatives (e.g. teleconferencing)
- More appropriate driver training focusing on "momentum driving" and use of acceleration.

| Cars | Buses | Passenger Rail | Domestic Air | Total Travel |
|---|---|---|---|---|
| 2.25 | 1.55 | 0.92 | 2.47 | 2.22 |

*Table 5.3: Passenger energy intensity (MJ/p-km) by mode, 2006 (Source: EECA)*

| Road | Frieght Rail | Coastal Shipping | Overall Freight |
|---|---|---|---|
| 3.15 | 0.44 | 0.37 | 2.38 |

*Table 5.4: Freight energy intensity (MJ/t-km) by mode, 2006 (Source: EECA)*

- Better traffic control to reduce urban congestion
- Mandatory fuel consumption rating endorsements on cars allow vehicle buyers to choose more energy efficient options

### 5.5.7 Central and local government actions

The New Zealand Energy Efficiency and Conservation Strategy (NZEECS) was launched in October 2007[1]. The NZEECS makes a number of recommendations about governmental responses to energy efficiency. These include:

- Govt3 agencies to have a sustainable procurement policy, including energy efficient products, in place by 2008.
- All new government buildings and leases above a threshold size must meet an energy efficiency standard that delivers best value over the whole-of-life by 2012.
- 70% of Govt3 agencies to purchase vehicles in the top 20% of fuel efficiency for class by 2009.
- 70% of Govt3 agencies to have a workplace travel plan in place by 2010.
- 10% reduction in energy use per full-time

[1] Jeanette Fitzsimons, 11 October, 2007, Energy efficiency steps up for a sustainable NZ. Speech notes for launch of the New Zealand Energy Efficiency and Conservation Strategy. Grand Hall, Parliament Buildings Wellington

http://beehive.govt.nz/speech/energy+efficiency+steps+sustainable+nz

*Figure 5.6: Example of a walking bus*

*Figure 5.7: Cycling (Source: ViaStrada Ltd)*

employee of premises occupied by Govt3 tenants by 2012 (compared with 2006).

- Stabilise the net emissions of air travel by Govt3 agency staff at 2006 levels by 2012.

The "3" in Govt3 stands for the "three pillars of sustainability"; environment, economy and society. In New Zealand, our government has shown leadership in this area by developing and implementing Govt3 across the public sector. It is anticipated that the NZES and the NZEECS will be reviewed later in 2009. http://www.bellgully.com/newsletters/14corporate/utilities_2.asp

## 5.6 Conclusion

The Parliamentary Commissioner for the Environment's report on local energy systems estimates that energy efficiency has the potential to save 1,101 GWh per year over the next five years - with savings rising to 7,755 GWh a year over a 30-year timeframe. This figure rises significantly if solar hot water systems are added into the mix. Solar hot water, both in domestic and industrial use, is projected to save an additional 897GWh a year over the next five years, rising to 8,201 GWH a year over the 30 year timeframe. This represents 38% of New Zealand's current net electricity generation of 41,622 GWh - and hence energy efficiency can provide a significant portion of NZ's future energy needs.

One of the keys to improving energy efficiency lies in changing consumer behaviour - both at business and domestic level. An important strategy for achieving this change is by educating the public through social marketing campaigns which inform about the benefits obtained from energy efficiency. These benefits lie not just in dollar savings to the consumer, but also in the less tangible but equally important goals of achieving health, social and environmental improvements.

# 6 SUMMARY OF RISKS AND OPPORTUNITIES FOR CANTERBURY

The key objectives of this *Draft Regional Statement of Opportunities for Energy in Canterbury* (RSOO) are to provide background and support material that will assist with the development of the Canterbury Regional Energy Strategy by:

a) Communicating the range of possibilities for regional energy investment (supply-side opportunities).

b) Communicating demand-side opportunities (e.g. energy demand reduction or demonstration projects).

This regional statement of opportunities for energy (RSOO) in Canterbury is primarily a desk-top initiative of existing available information as applied to the Canterbury Region. This is a starting point to provide an initial overview of the energy options in the Canterbury Region that can be built upon in the development of a greater Regional Energy Strategy with stakeholder and community involvement.

The relationship of this Regional Statement of Opportunities (RSOO) report, to Regional policy and planning is highlighted in Table 1.1 Responses to pressures on energy.

Canterbury plays a significant role in the national energy supply. Its development has always been greatly influenced by national needs which in turn are driven by international issues. Consideration of global energy issues therefore provides the reference frame for what trends and technology we might expect to see in New Zealand. These matters are of great interest to the National Grid Operator, Transpower, who are currently conducting a scenario planning exercise for the purpose of updating their long term Grid Development Strategy; Transmission 2040. Transpower has identified the following critical uncertainities: International fuel price, cost of carbon, government energy policy, climate change, new technology and resource planning requirements (RMA). Population growth rates in different areas are also an uncertainty.

According to the medium series of the 2006-base sub-national population projections (released December 2007), 12 of New Zealand's 16 regions and 40 of 73 territorial authority areas are projected to have more residents in 2031 than in 2006. However, population growth will slow over the projection period in all areas. For the medium series, based on medium fertility and mortality, and a long term annual net migration gain of 5000, the growth rate in Canterbury reduces from 1.7%/annum for the years 2001 to 2006, to 0.7%/annum for the period 2006 to 2031. For the same series, New Zealand population is projected to plateau at around 4.7 million from 2036 onwards.

There are a range of barriers that have slowed the uptake of renewable energy. These largely relate to the need for individual projects to secure their own 'fuelÓ supply from natural resources while also still having to construct an energy conversion facility (*i.e.* power plant). The locations where these natural resources are found often have other intrinsic value (such as wind resources found in areas of high landscape value, or hydro opportunities in dramatic catchment areas) or the resource itself has other competing uses (such as recreational use of rivers or geothermal features as tourist attractions).

## 6.1 Possibilities for regional energy investment (supply-side opportunities)

### 6.1.1.1 Canterbury Hydro Energy

Rounded totals for the remaining potential hydro capacity (MW) for each of the eight catchments have been shown earlier in the report. The sum of the rounded totals is **3590 MW**. Much of this will be in the too hard basket, or not economic.

#### 6.1.1.2 Water: From West to East

There is a concept proposal to divert water, from high elevation catchments west of the Main Divide with annual rainfall of over 8000 mm, through tunnels to a power station (22 MW) near the airport at Mt Cook. The diverted water then passes through 6 or more further power stations. Based on a flow rate of 20 $m^3/s$, this extra diverted water is estimated to produce 450 GWh annually. This can be compared with the storage in Lake Pukaki at 1679 GWh. (*Water: From West to East* by Norman Hardie in Constructing New Zealand, Feb 2009)

#### 6.1.1.3 Project Dustorm by John de Bueger

This concept proposal is for increased hydro storage at Lakes Tekapo & Pukaki. Water storage has value in that the water would otherwise be spilt and not be used for generation. The project offers:

- Extra 5% storage in both lakes without affecting the containment structures.
- Lake-heads returned to the pre-hydro Ônatural' condition.
- Permanent fix for Tekapo dust storms – allowing better use of existing storage.
- Low cost 500 GWh strategic reserve.
- Invisible on completion.

#### 6.1.1.4 Water Storage

New large scale hydro and/or irrigation storage would also allow value to be created during times of excess wind and hydro spill. However there is no provision in the Waitaki District Plan to permit the construction of a suitable transmission line i.e. it would be a non-permitted activity. There are many locations in the Waitaki district suitable for building large scale hydro storage that can be applied to both irrigation and electricity security. Pumped storage to use excess energy should not be overlooked. Pumped storage is used when there is little control over the availability of generation such as wind or when base load generation has limited ability to back-off such as thermal and nuclear plants. Pumping allows them the run at optimum level over night and the storage is used for peaking during the day. (Waitaki Report Dec 2008)

Schemes that combine hydro and irrigation are more likely to have better prospects.

#### 6.1.1.5 Meridian and South Canterbury Irrigation Trust proposal for South Canterbury

Meridian Energy and the South Canterbury Irrigation Trust (a collaboration between Timaru, Waimate, and Mackenzie District Councils) plan a major sustainable irrigation initiative for South Canterbury. The Hunter Downs Irrigation scheme initiative with Meridian Energy has the potential to transform the South Canterbury district, from Waihao to as far north to Otipua, and which could drive regional economic growth for many years to come.

There are synergies between hydro and irrigation. What is not clear is the potential for recovery of energy used in pumping as the water flows down to the various farm properties.

#### 6.1.1.6 Hurunui Water Project

Water from storage and the distribution of the water down the slope of the plains (1 in 170) provides the opportunity for small scale generation. There is already potential for small scale generation at the drop structures on the existing irrigation canals and the raceways.

#### 6.1.1.7 Irrigation Races

Since 2002, *water turbine drives for irrigation pumps* which cost virtually nothing to run, have been installed on Mid-Canterbury irrigation schemes. Further installations on the Mid-Canterbury irrigation schemes have been built saving farmers many thousands of dollars in either diesel or electricity pumping costs. These small scale developments may need planning support from the irrigation company, the local council, and the network company.

#### 6.1.1.8 Micro hydro

In total the contribution of Ômicro' hydro is likely to be significant. However the potential has never been identified, for obvious reasons – including: dispersed nature of the resource, technical and regulatory complexities, proportionally high development overheads, and landowner issues.

### 6.1.2 Marine Energy

#### 6.1.2.1 Wave Power Devices

Many wave device designs are under development and there is, as yet, no convergence on a common design. Selection of device type would be critical in the less productive east coast locations (Canterbury) but device survival (and capacity factor) are likely to be bigger issues at the more energetic locations.

To illustrate the attainable power potential, a simple case study based upon resource potential and assuming Pelamis deployed technology may be considered to demonstrate the wave power extraction viability. Operating in the 18 kW/m wave climate environment, each unit would produce around 130 kW (significant wave height 1.8 m and wave period of 8 seconds), and spacing the units 150 m apart, a farm array of 14 devices would occupy a foot print of 2100 m by 150 m.

Assuming the developers quoted load factor of 40%, the annual energy production per unit would be 455 MWh, which approximates to 6.37 GWh per farm. At a 40% load factor, this equates to an average output of about 2 MW. (SKM 2006)

SKM estimate that with a Canterbury coastline length of around 400 km, a capacity potential from wave energy in the **thousand megawatt range**, ignoring environmental constraints and conflicts with other marine users. The west coast and Southland have significantly more energetic sites close to the shore.

#### 6.1.2.2 Tidal Power Devices

There are currently no identified significant opportunities for tidal current devices on the Canterbury coast.

#### 6.1.2.3 Ocean temperature gradients

These can be exploited by means of heat engines. Without a temperature difference of 20˚C, Ocean Thermal Energy is not an option for Canterbury.

#### 6.1.2.4 Osmotic Power

When freshwater meets saltwater, for example where a river flows out into the sea, enormous quantities of energy are released. This energy can be utilised to generate power through the natural phenomenon of osmosis. Energy created by osmosis has very little impact on the environment and the process does not "consume" the salt. Osmotic-produced power is much more expensive than for example fossil fuels and there are engineering problems to be overcome.

### 6.1.3 Geothermal Power

#### 6.1.3.1 Conventional geothermal systems

There are no known resources available in Canterbury for conventional geothermal power generation.

#### 6.1.3.2 Engineered geothermal systems

This is where a heat source is present but lacks a reservoir. This has to be artificially engineered. It is also referred to as hot rocks or hot fractured rocks (HFR). HFR is a type of geothermal power production that uses the very high temperatures (of about 200 degrees Celsius) that can be found in rocks a few kilometres below ground. Electricity is generated by pumping high pressure water down a borehole (injection well) into the heat zone. The water travels through fractures in the rock, capturing the heat of the rock until it is forced out of a second borehole as very hot water, which is converted into electricity using either a steam turbine or a binary power plant system. All of the water, now cooler, is injected back into the ground to heat up again in a closed loop. See Fig 3.9. HFR technologies, like hydrothermal geothermal, are expected to be base load resources which produce power 24 hours a day like a fossil plant.

Hot Dry Rock technology is not promising in Canterbury as it does not appear to have a high crustal thermal gradient and its volcanic nature poses potential difficulties creating the required underground fractured rock heat exchangers. However, this may need further study. Drilling is the single most costly item for EGSs. Development of hydrothermal drilling techniques could significantly reduce drilling costs. If this development succeeds, geothermal power will be practical virtually anywhere.

From an Australian study HFR geothermal energy can be produced more cheaply than all other electricity generation options if the cost of carbon emissions is factored in (see Figure 6.1).

### 6.1.4 Wind

#### 6.1.4.1 Wind Farms

Wind farms in the Canterbury region are expected to be in the 50-150 MW range, and

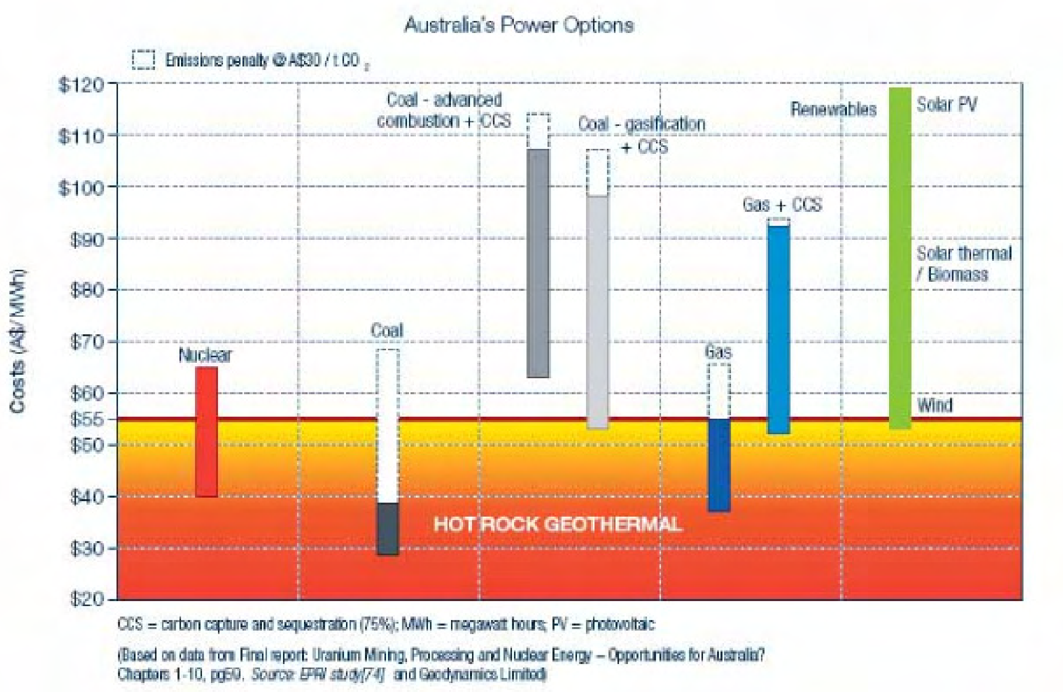



*Figure 6.1: Australia's Power Options (http://www.geodynamics.com.au/IRM/Company/ShowPage.aspx?CPID=1405)*

located some distance from each other so that cumulative effects, primarily adverse visual impact, are less likely. Five to ten wind farms of that size could potentially be developed based on an initial screening of the region taking into account wind resource, topography, population density, distance to grid, accessibility and environmental factors (*e.g.* native forest and DoC land). At current market conditions a lot of the potential wind farm sites in the region are probably only marginally economically viable. Rising electricity prices may have changed this.

The development of wind farms in the Canterbury region has caused controversy as it does in other regions of the country. If carefully planned, approximately 1000 MW of wind capacity could be installed over a number of years with environmental impacts that are broadly acceptable to local communities. The technically available potential is much larger. Small scale wind turbines are not expected to play a significant role in future electricity generation, but they can become important for remote farms and settlements.

#### 6.1.4.2 Medium scale wind sites

Wind is also viable at a smaller distributed generation scale. That is, small wind farms up to a few MW in capacity, with up to 3-4 turbines. Viability results from smaller scale allowing lower quality wind resources to be used which are located closer to existing electricity networks and so avoid the need for expensive network upgrades. Further the risk is lower and so less effort is required to monitor wind before development. Second hand wind turbines are readily available for this type of rapid implementation development. The total number of these sites exceeds the need from local use perspective. Approximately 30MW of wind generation is estimated to be adequate from an optimal system perspective. This scale of development is well within the scope of farming business to fund and could be used in the future to off-set power charges. Currently, even such small scale generation of any type is not a permitted activity in the most(?) District Plans.

### 6.1.5 Solar Energy

Solar radiation for the Canterbury Region is approximately 1350 kWh/m$^2$/yr, with no large variations across the region. However an area near Lake Tekapo has more solar radiation than Melbourne.

#### 6.1.5.1 Solar Energy Generating Systems

Trough systems predominate among today's commercial solar power plants. In Australia a medium-sized (50 MW equivalent) solar steam generating system is being built for power augmentation (booster) systems to deliver steam into an existing fossil-fuelled (coal) power plant, increasing power output and reducing carbon emissions.

#### 6.1.5.2 Potential for Solar Thermal (Solar Water heaters)

Households account for 42% of electricity demand in the Canterbury Region (EECA, 2004). Of this, about one third is usually for water heating (BRANZ 2004). A standard solar thermal system can produce around 55% of a household's water heating. Hence, the installation of solar thermal technologies has the potential to address some of the region's overall supply issues. Solar thermal systems are most economic when installed in new buildings. The areas with high demand in new housing are best suited for promotion and installation of solar thermal systems.

#### 6.1.5.3 Potential for Solar Photo-voltaic (PV)

The biggest barrier for the large scale uptake of PV is the high cost of the technology. Consequently, uptake has predominantly been for remote power supplies, enthusiast users and commercial developments where renewable energy has additional value as a corporate strategy or image statement. In summary, the current high costs of solar photovoltaic means that large scale grid connected uptake in the region is unlikely in the short term, however small scale applications, particularly for remote power supply are expected to become more popular. On 25 February 2009 First Solar Inc. (Arizona, United States) announced it had reduced its manufacturing cost for solar modules to US $0.98/watt, breaking the $1 per watt price barrier that the industry has been striving towards in recent years. It is confident that further significant cost reductions are possible based on the yet untapped potential of its technology and manufacturing process. Manufacturing capacity has grown to more than 500 MW in 2008 and annual production capacity will double in 2009 to more than 1 GW, the equivalent of an average-sized nuclear power plant.

#### 6.1.5.4 Potential for Passive Solar Building Design

Solar space heating can significantly reduce the amount of energy use in new buildings. With solar space heating, the building is designed to maximise the absorption of solar energy. This can be applied to any building regardless of size or use (domestic/commercial). The building design considers building placement and orientation on the site and design features to capture, store and release solar energy in the building. Solar building design not only reduces the energy use, but it also can reduce moisture and condensation, improve sound insulation and provide a generally more comfortable and healthy living environment.

There is a need for local authorities to address solar access issues. District plans will need to be modified so that they take a more positive approach to the promotion of sustainable development practices.

### 6.1.6 Wood as a fuel

Burning firewood is considered carbon neutral and typically uses materials that would otherwise be wasted and left to rot and decay giving off methane etc.

Burning wood in a wood stove to heat water has significant potential. Poorly designed units need to be replaced to limit urban air pollution. Appropriate testing for compliance with set limits of emissions is essential. The sight of flames and burning fuels is attractive to many people.

For the next 20 years, both the quantity and the quality of the wood that will be harvested have been set by the forests already established and by their management. However, development of some very short-rotation crops for bioenergy production may be possible.

### 6.1.7 Biogas

An example of a life cycle assessment for effluent to combined heat & power (CHP) via anaerobic digestion to biogas in Canterbury shows this to be economic at favourable sites.

### 6.1.8 Bio fuels – (Biomass)

Canterbury has a range of bioenergy options available that could provide a meaningful contribution to Canterbury's energy future. Canterbury has the potential to fuel itself from renewable resources. This ability is due to a low population density and large areas of land suitable for agriculture and forestry. It is theoretically possible for New Zealand to be self sufficient in terms of liquid fuels by using sustainably managed forests, while having low impact on domestic and export food production. Along with the energy will come ancillary benefits of forests including flood mitigation, improved water quality, erosion control and carbon sequestration.

[Source: SCION Next generation biomaterials – Bioenergy Options for New Zealand, Nov. 2007]

Key Conclusions:

- All available biomass residues combined would meet only 10% +/- of New Zealand's current energy demand. Woody biomass is the bulk of this material.
- Purpose grown crops will be required to meet a larger proportion of New Zealand's energy demand.
- Steep hill country will need to be used for growing this extra biomass to avoid conflict with agricultural production.
- The only viable biomass crop for steep lands is forests, which have additional uses, environmental benefits and can act as a significant energy store.
- Research is required on a range of conversion technologies to improve their economic viability, as well as forest and agricultural crops and algal systems.

## 6.1.9 Energy from Waste

### 6.1.9.1 Waste to Renewable Energy

At Burwood landfill methane was a problem; as organic material rots in an oxygen-free environment, so landfill gas, including methane (approx. 59%), is produced. To destroy the gas the solution is normally to collect and burn it off in a flare. Instead of regarding the landfill gas as a worrisome item to eliminate, landfill gas may be used in sustainable projects to generate heat and electricity.

### 6.1.9.2 Incineration-based Waste-to-Energy Technology

Despite being an attractive technological option for waste management, combustion-based processes for municipal solid waste (MSW) treatment are a subject of intense debate around the world. In the absence of effective controls, harmful pollutants may be emitted into the air, land and water which may influence human health and environment.

### 6.1.9.3 Anaerobic Digestion

Anaerobic Digestion has a great future amongst the biological technologies which will become the tools for sustainable waste management throughout the 21st Century, working with nature to maintain the natural carbon cycle to the benefit of man. An on-farm energy system BioGenCoolTM transforms cow effluent into power that is used to heat and cool while providing a greatly reduced electrical load.

### 6.1.10 Gas & Oil

The occurrence of oil and gas in the Canterbury region has been well documented.

See information in Section 3.

### 6.1.11 Coal

The Canterbury region contains an inconsequential amount of New Zealand's coal resources.

#### *6.1.11.1 Coal seam gas – carbon neutral CSG*

The assessment of the coal seam gas potential has been undertaken in a staged programme. Preliminary assessment of the data on the permit areas indicates that the potential resource may be up to 500 PJ. To date, preliminary appraisals have been completed or are underway on a significant number of fields. Exploratory drilling has been completed or initiated on several of those fields, with results from this work being fed into the preliminary modelling as it has become available. Given that in many of these areas there is no pre-existing information concerning their gas potential and world wide experience with lignite is practically nonexistent, it has been a steep learning curve with many surprises. However, initial gas content results and preliminary gas flow models have been on the whole, rather pleasing, with the commerciality of some developments already apparent. There may be potential for piping gas from Otago & Southland

#### 6.1.12 Nuclear Power

In a report from Jack Woodward, he concludes that there is no reactor that could realistically be deployed in New Zealand (and more so in Canterbury) within present planning time frames.

## 6.2 Demand-side opportunities

***Demand Reduction – Canterbury region energy efficiency and conservation techniques.***

The arguments for using energy more efficiently are compelling. Such programmes increase efficiency, reduce energy costs, improve air quality and conserve natural resources and allow longer lead times for the development of new electricity generating facilities

The ongoing development of technology and increasing energy prices mean that new, more efficient technologies constantly become available. This means that there is generally potential to improve the efficiency with which we use energy to support various aspects of our lifestyles and industrial activities. Achieving that potential requires the replacement of existing technologies at the end of their life with more efficient technologies. It is often also cost efficient to replace existing technologies ahead of their expected lifetime, or before they are worn out completely.

'Potentials' are typically quantified at three levels: Technical potential, economic potential and market potential. Realising potentials is constrained by behavioural, technological, economic and takeback constraints. Only recently have the complex interaction of factors that alter energy efficiency potentials started to be assessed. Takeback: There are real limitations to potentials in that typically new energy technologies provide both service or productivity improvements as well as energy savings.

The benefits of demand-side driven energy efficiency are available to business and domestic consumers, as well as the providers of electricity infrastructure, and the environment

The built environment presents us with a major challenge. The construction, fit-out, operation and ultimate demolition of buildings is a huge factor in human impact on the environment both directly (through material and energy consumption and the consequent pollution and waste) and indirectly (through the pressures on often inefficient infrastructure). The built environment also has a crucial impact on the physical and economic health and well-being of individuals, communities and organisations.

Sustainable development is now stated policy of local, national and international governments, and much industry and commerce. There appears at last to be a growing commitment to reverse unsustainable trends in development. To meet the challenge we have to enhance quality of life for all by designing healthy buildings and environments fit for individuals and communities now and in the future.

### 6.2.1 Residential Sector

Suburban building sites. Solar-effective houses cannot be placed on unsuitable suburban sites.

***General Building Design***

The Home Energy Rating Scheme allows potential home buyers to have a quantitative estimate of a building's energy efficiency in design. It is likely that in the future the Councils will hold (and possibly record on Land Information Memoranda) additional information such as the energy efficiency rating data under the Home Energy Rating Scheme (HERS).

Guides promoting sustainable building design and building site selection and planning are available

Estimates suggest that the Canterbury region has more than 100,000 homes that have been built prior to the requirement to have any basic insulation. Schemes to make Canterbury families healthy need support. Research from the Wellington School of Medicine shows that for every dollar spent on insulating cold houses, there is a two dollar return in energy and health savings.

Higher-than-Code levels of insulation will be justifiable for many new houses in Canterbury. There is a need for guidance – either through HERS or by updating the Ôbetter' and Ôbest' levels of insulation previously provided through SNZ PAS 4244:2003.

**Thermal mass** - reduces heating requirement after natural heating periods. Heat is stored within the living space without excess temperatures and significantly improves comfort, reduces overheating. Good design should mean that air cooling is not required in Canterbury homes.

**Glazing** - Orientation and size of windows to limit/increase solar energy gain

**Ventilation** - From an energy efficiency standpoint, ventilation should be designed and controlled.

**Active Space heating** - Replace low efficiency heaters (e.g. open fires) with more efficient devices (e.g. log burners, pellet fires). Increase use of cheap materials (i.e. wood) for space heating. Wood fires may be considered to be $CO_2$ neutral.

At the municipal level, incorporating centralized heating systems would be an excellent sink for low-grade heat from power stations/industry. Cooling needs should be avoided by good design using thermal mass and night ventilation.

Increase solar hot water heating systems, hot water heat pump usage, and appropriately designed wood fuel burners (combined with space heating) in place of just electric furnaces to improve efficiency.

Solar energy used directly for heating water or buildings is not counted as part of the energy supply.

**Lighting** - Average annual energy use for lighting in Canterbury is 530 kWh/house

Replacing incandescent light bulbs with compact florescent bulbs

Avoid and replace cheap recessed light fittings with thermally better fittings and lamps.

**Local generation** - Plan for incorporating solar photovoltaic panels into roofing and walls.

Provide solar access rules to protect installations from future shading, particularly trees on neighbouring properties.

**More efficient appliances** - average annual energy use in Canterbury for refrigeration is 800 kWh/house and for all cooking is 990 kWh/house. Support the minimum energy performance standards (MEPS).

**Energy management** – Running appliances represents approximately 20% of energy consumption - with almost 5% of energy used to run appliances in standby mode. Encourage improved behaviour towards energy conservation – automatic switches or turning off appliances at walls when not in use, and turning off lights.

**Toolkit for local councils** – Beacon Pathway Limited (Beacon) is preparing a toolkit for local councils that will identify and develop best practice approaches to sustainable residential developments. An important aspect of the toolkit will be best practice in terms of district plans and related regulatory tools under the Resource Management Act 1991 (RMA).

#### 6.2.2 Commercial Sector

Building Design. The New Zealand Green Building Council has developed a 'Green StarÓ rating system for commercial buildings. The system will be an important benchmark tool for raising energy efficiency measures and thereby contributing towards energy sustainability.

#### 6.2.3 Industrial Sector

Distributed Generation (DG). A plant producing its own electricity and using the heat/cooling cycles as a byproduct (co/tri-generation) are together more efficient than dedicated heat/cooling plant + mains electricity.

#### 6.2.4 Agricultural (Primary Production) Sector

- Distributed Generation
- Reduction of the use of energy intensive agricultural products
- Use of alternative fuels or energy
- Plant maintenance and retrofitting
- Use of heat recovery from waste

#### 6.2.5 Transportation Sector

The National Energy Efficiency and Conservation Strategy (October 2007) has a transport action area that includes:

- managing the demand for travel;
- more efficient transport modes;

- improving the efficiency of the transport fleet;
- developing and adopting renewable fuels.

The Canterbury Regional Land Transport Strategy 2008-2018 has no details on the energy issue of developing and adopting renewable fuels.

Electric vehicles: By 2050, the government sees 60% of New Zealand's (non-heavy freight) vehicles will be electric - with those using fossil fuel dropping to just 2% of light vehicles on the roads. Substituting fossil fuels with electricity in the transport sector is considered a very likely scenario with the majority uncertainty being around how much substitution will take place and the timing. Electric motors are 80-95% efficient. Internal combustion engines in cars only achieve about 13-20% (average 17%) efficiency. Even if electric vehicles gained a 60 per cent market share by 2040, they would use only 15 per cent of current power demand.

Alternative transport methods – walking school buses & cycling. Most councils have now developed either walking or cycling strategies (or both). However, most need to develop, update or finalise their walking or cycling strategies.

#### 6.2.6 Conclusion

The Parliamentary Commissioner for the Environment's report on local energy systems estimates that energy efficiency has the potential to save 1,101 GWh per year over the next five years - with savings rising to 7,755 GWh a year over a 30-year timeframe. This figure rises significantly if solar hot water systems are added into the mix. Solar hot water, both in domestic and industrial use, is projected to save an additional 897GWh a year over the next five years, rising to 8,201 GWH a year over the 30 year timeframe. This represents 38% of New Zealand's current net electricity generation of 41,622 GWh - and hence energy efficiency can provide a significant portion of NZ's future energy needs.

One of the keys to improving energy efficiency lies in changing consumer behaviour - both at business and domestic level. An important strategy for achieving this change is by educating the public through social marketing campaigns which inform about the benefits obtained from energy efficiency. These benefits lie not just in dollar savings to the consumer, but also in the less tangible but equally important goals of achieving health, social and environmental improvements.

## 6.3 Overview

Because of the limited nature of this SOO, it has not been possible to provide a full assessment of the opportunities potentially available to the region to meet future energy needs. However, there is in the public domain a significant body of literature that describes these possibilities and the contributions that might ensure.

Some specific case studies (opportunities) that could be examined further include:

1. Oil exploration – Canterbury Basin exploration projects
2. Natural gas – gas field associated with oil exploration
3. Coal bed methane – produced in Otago/ Southland coal fields but end users in Canterbury
4. Hurunui Irrigation and Power Project – irrigation of ca 500km2 and power generation.
5. Water development projects based on the Waitaki Basin.
6. Support for the development of energy sustainability plans for the district councils involving the local community.

Much more needs yet to be done to give effect to these opportunities and to clarify possible future pathways. What is generally missing from the published information is a realistic appraisal of the price points at which individual supply options are likely to become commercially viable.

This study has continued the process of assessing the vulnerabilities and opportunities to the Canterbury region for meeting its future energy needs. The discussion in the earlier sections of this report suggests that there is a range of risk factors likely to influence future supply pathways. These factors range from institutional capabilities through to demographic trends and specific location and supply chain issues.

Because of the limited nature of this SOO it has not been possible to assess these issues in depth, nor have we sought to provide a full assessment of the opportunities potentially available to the region to meet its future energy needs. We are conscious that there is in the public domain a significant body of literature that describes these possibilities, but what is missing is a realistic appraisal of the price points at which individual supply options are likely to become commercially viable. The case studies described in this report thus merely seek to describe the nature of these opportunities and the likely ways forward. Much more needs yet to be done to give effect to these opportunities and to clarify possible pathways. The critical vulnerabilities facing the region are exposure to price shocks from supply disruption and/or increasing capacity constraints.

Energy poverty is defined by the number of households that need to spend more than 10 percent of their income on fuels to keep warm and to service an adequate lifestyle. However, we also have to take into account the ways in which we use energy.

New Zealand, for example, is around 50 percent of that of comparable economies elsewhere in the world. This low value reflects the low levels of space heating (houses may be energy efficient but are poorly heated) and also the nature of our housing stock.

The comparative higher heating requirement for South Island homes, combined with air quality regulations forcing householders to have a greater reliance upon a formal fuels market and/or appliance upgrades is reinforcing an inevitable trend of a greater proportion of households spending more than 10 percent of their income on fuel. There is much more work yet to be done to quantify and assess the likely implications of this and the other trends identified by the report. However, in the short term we believe the following trends can be seen right across the fuel supply chain.

- Air quality legislation will drive a higher standard in wood drying and force a shift to a more formal market (including wood pellet) and a greater reliance on a single distribution channel. This situation will have an immediate effect on fuel choices for new home builders/renovators and long term effects on future choices with the likelihood of continued fuel switching to either electricity or LPG.
- Coal is unlikely to be a significant player in the local market. Whilst there is a long established market in place with relatively lower transport costs, industrial users are coming under increasing pressure to find alternatives. Without incentive towards clean coal technology or assistance to industry users to upgrade current facilities we are likely to see fuel swapping and thus increasing price pressures transferring into the domestic market, or simply the transfer of industry to other regions.
- LPG should be viewed as a critical supply chain. LPG is supplied from sources external to Canterbury and is dependent on specialized equipment and a specialized supply chain. Regional supply is linked to the vagaries of the world's oil markets and thus will always face this exposure and, as well, increasing demands have the potential to place pressure on current storage levels. Public opposition has a serious effect on the ability to increase storage or put in new storage due to the perceived risks of LPG storage.
- Vulnerability to international oil prices manifests itself most in the farming and tourism sectors. The sectors are very reliant on transport fuels and are thus vulnerable to supply failures. Pricing changes and price shocks, including those incurred by changes in the NZ dollar value will have an effect on economic activity.
- Whilst the Canterbury Basin is seen as an excellent prospective oil and gas exploration opportunity, the economic value of the region's petroleum resource will be dependent on exploration success and international investment. Regional decision makers have significantly undervalued the value of the resource to the region in the past, and this needs to change if exploration investment is to be attracted to the region. In addition to the above it is also worth reflecting upon the interdependencies that govern infrastructure resilience end our capacity to cope with a major disruptive event. In particular

we comment that a secure and reliable electricity supply is essential to our modern lives. Common examples of such dependency referred to in this study and often overlooked include

- Older style pellet fires require electricity to operate
- Gas hot water systems require electricity for control operations.
- Communication systems require 'mains' supply to recharge.
- Water supplies, fuel supplies, control systems and signalling, transport and a myriad of other application all rely on electricity.

Addressing these issues is a lifelines engineering issue, an area that Canterbury has undoubted capacity, but unfortunately our experiences dictates that collaboration and cooperation is essential if we are to appropriately manage these risks. Because of the regions strong reliance on electricity for both manufacturing and domestic use, Canterbury retains a particular vulnerability in these areas.

Finally we comment that Canterbury as a region has available to it substantial opportunities from increased regional energy supply from distributed generation investment and potentially from other non-conventional energy sources. Properly addressed and sensibly progressed these resources have the potential to deliver considerable economic benefit and energy security to the region. The extent of these resources remain largely undefined and their potential contributions uncertain. These opportunities compete with the economies of scale delivered by larger schemes by supplying energy close to the point of use. The key to any strategy that seeks to encourage local supply is diversity of both location and mix of generation. The benefits of diversity enable economic development while also contributing to resolving the capacity and security issues being driven by demand growth and requirements for improved power quality.

The way forward will require the region to better articulate these critical energy issues and decide on the tradeoffs needed to bring together a portfolio of opportunities deserving of more analysis and investigation. A lack of coordination at the regional level, incumbent players continuing with conventional business modes, and changing demographics and load patterns all combine to leave the region vulnerable to sub optimal outcomes and thus a failure to meet consumer expectations for a reliable and affordable energy supply.

for a valuable input into everyone's understanding of the issues facing New Zealand's wholesale electricity sector, see Meridian Energy publication (2009 update) *Choices*, identified in Appendix F.

# 8 APPENDICES

# Appendix A: Units

### 1.Multiples

| Prefix | Symbol | Factor | Term |
|---|---|---|---|
| kilo | k | $10^3$ | thousand |
| mega | M | $10^6$ | million |
| giga | G | $10^9$ | billion |
| tera | T | $10^{12}$ | |
| peta | P | $10^{15}$ | |

### 2. Power:

The unit for measuring power is the Megawatt (MW). Power is the rate at which energy is generated /consumed, i.e. 1MW means that one million joules of energy is generated / consumed every second. As crude approximations: a full petrol tank in an average size car contains one million joules of energy; a single wind turbine has a 1MW capacity. (SKM 2006)

**3. Energy:** In the electricity industry, energy is measured in kilowatt hours (kWh), sometimes referred to in context as "units", or, for large quantities, gigawatt hours (GWh). 1 GWh = 1,000,000 kWh. A device with a rating of 1,000 watts or one kilowatt running for one hour would consume one kilowatt hour of electricity. A similar device running for half an hour or two hours would use 0.5 kWh or 2 kWh respectively.

1 PJ = $10^{15}$ joules
= 277.778 gigawatt hours (GWh)
= $0.2388 \times 10^5$ tonnes of oil equivalent (toe)
1 kWh = 3.6 MJ

# Appendix B: Previously Identified Hydro Schemes

| No | Catchment Area/River | Head | Flow (1) | Capacity | Energy | Remarks |
|---|---|---|---|---|---|---|
| | | (m) | ($m^3/s$) | (MW) | (GWh) | |
| | **Waiau, Clarence and Coastal Kaikoura** | | | | | |
| C1 | Boyle River (3) | 55 | 6.9 | 3.2 | 14 | |
| C2 | Kakapo Brook (3) | 180 | 3.25 | 5 | 22 | |
| C3 | Waiau Irrigation | 11 | 9.5 | 0.9 | 4 | |
| C4 (3) | Clarence C171 | | | | | 70 MW, Divert water out to Waiau catchment, hence clashes with all schemes on the river d/s |
| C5 | Clarence C141 /Conway (3) | | | | | 300 MW, diverts water to Conway, addional 180 MW with another PS on the coast near Oaro |
| C6 | Clarence C109 (3) | | | 60 | | |
| C7 | Clarence (3) | | | 150 | | |
| C8 | Lower ClarenceRiver (3) | 120 | 35 | | 0.0 | 35 MW, Alternate if C7 is not built |
| C9 | Conway River | 40 | 13 | 4.3 | 18.8 | 4.3 MW, Conflicts with C5 |
| C10 | Hope River (3) | | | 55 | | |
| C11 | Waiau W108 (3) | | | 375 | | 46 MW |
| C12 | Waiau W97 (3) | | | | | 56 MW |
| C13 | Waiau W81 (3) | | | | | 60 MW |
| C14 | Hurunui – Waiau H71 | | | | | 25 MW, Power station at banks of Pahau if diversion from Hurunui to Waiau is constructed |
| C15 | Hurunui – Waiau W72 | | | | | 120 MW if diversion from Hurunui to Waiau is constructed |
| C16 | Hurunui - Waiau | | | | | 105 MW if diversion from Hurunui to Waiau is constructed |
| C17 | Waiau W21 | | | | | 140 MW if diversion from Hurunui to Waiau is constructed |
| C18 | Waiau W2 | | | | | 50 MW if diversion from Hurunui to Waiau is constructed |
| | **Hurunui** | | | | | |
| C19 | Lake Sumner Outlet (a) (3) | 16 | 32 | 4.3 | 19 | Lake Sumner Outlet (b) (Alternative with 30m head -8MW and 35GWh) |
| C20 | Sisters Stream (3) | 21 | 4.2 | 0.73 | 3 | |
| C21 | Hurunui North Branch Dam site No 1 (3) | 46 | 46 | 17.6 | 77 | Alternative Dam site 2 - 90 m head with 54 m3/s - 40MW and 175GMh |
| C22 | Hurunui-Balmoral Irrigation / Hydro (a) | 24 | 5 | 1 | 4 | Alternative with 20m3/s - 2MW and 11.1GWh |
| C23 | Hurunui No.2 (3) | | | 37 | | |
| C24 | Hurunui No.3 | | | 64 | | |
| C25 | Hurunui H36 | | | 43 | | Reduced capacity If C14 – C16 constructed |
| C26 | Hurunui H24 | | | 36 | | Reduced capacity If C14 –C16 constructed |
| | **Waipara and Ashley** | | | | | |
| C27 | Ashley River - Dam(3) | 37 | 25 | 7.7 | 34 | There is an alternative run of river scheme with 30m head 20m3/s - 5MW 21.9GWh |
| | **Waimakiriri** | | | | | |
| C28 | Cass 5 (3) | 144 | 2 | 2.25 | 10 | There are two alternatives of 0.11MW and 0.22MW |
| C29 | Broken river (3) | 134 | 8 | 8.7 | 38.1 | |
| C30 | Poulter River Dam | 74 | 64.1 | 38.9 | 170 | There are alternatives with the dam at |

| | | | | | | |
|---|---|---|---|---|---|---|
| | to RL 533 m (3) | | | | | RL 518 of 31.2MW or RL 488 of 15.4MW |
| C31 | Waimakariri – head of Gorge | | | 60 | | Alternative is 15.7 MW diversion scheme that conveys water from u/s of the gorge to PS on the south bank of Waimakariri R. |
| C32 | Waimakariri – foot of Gorge (3) | | | 80 | | |
| C33 | Waimakariri | | | 91 | | |
| | Waimakariri - Lower reaches (2) | | | | | 300 MW, Details not available |
| | **Rakaia, Selwyn and Banks Peninsula** | | | | | |
| C34 | Rakaia Canal Scheme Proposal A | 33 | 70 | 19.7 | 123 | There are alternatives of 14.1MW @ 50m3/s and 28.2MW @ 100m3/s |
| C35 | Rakaia Canal Scheme Proposal C | 25 | 70 | 14.5 | 91 | There are alternatives of 10.7MW @ 50m3/s and 21.3MW @ 100m3/s |
| C36 | Lake Stream / Rakaia | 120 | | 22.5 | 99 | |
| C37 | Wilberforce River (3) | | | 55 | 245 | Expansion of Lake Coleridge power scheme, capacity increase over existing 35 MW |
| C38 | Rakaia River | | | 230 | 1000 | |
| | Rakaia River (2) | | | | | 320 MW in the lower reaches, Details not available |
| | **Rangitata and Ashburton** | | | | | |
| C39 | Bush Stream | 400 | | 30 | 130 | |
| C40 | South Branch Ashburton / Rangitata | 244 | | 52 | 226 | Alternative with 247m head - 27MW and 119GWh |
| C41 | Potts River | | | 35 | 150 | |
| C42 | Rangitata River | | | 85 | 370 | Alternative is a 40 MW ROR scheme with dam at u/s end of Rangitata Gorge and PS at d/s end. (Head 54 m) |
| | **Opihi-Orari and Coastal South Canterbury** | | | | | |
| C43 | Opua River | 85 | | 9.5 | 42 | [Scheme has been completed] |
| | **Waitaki** | | | | | |
| C44 | Jacks Stream | 360 | | 4 | 18 | |
| C45 | Boundary Stream | 290 | | 2.4 | 10.5 | |
| C46 | Lower Waitaki Irrigation - McPhersons Rd 2 | 20 | 14 | 2.33 | 10 | Alternative $6m^3/s$ - 1MW - 4.3GWh or $16m^3/s$ &10 m head - 1.33MW and 5.8 GWh |
| C47 | Waiareka – Kakanui Irrigation P/H No. 1 | 50 | 22 | 9.17 | 40 | |
| C48 | Waiareka – Kakanui Irrigation P/H No. 2 | 10 | 22 | 1.83 | 8 | |
| C49 | Maerewhenua River | 60 | 4.3 | 2.15 | 9 | |
| C50 | Otekaieke River | 60 | 1.7 | 0.85 | 4 | |
| C51 | Hakataramea River | 47 | 3.8 | 1.5 | 7 | |
| C52 | Otematata River | 30 | 6.2 | 1.55 | 7 | |
| C53 | Ahuriri River – Avon Burn P/H No. 1 | 26 | 20 | 4.4 | 27 | |
| C54 | Ahuriri River – Avon Burn P/H | 10.5 | 20 | 1.8 | 11 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | No. 2 | | | | | |
| C55 | Ahuriri River – Hen Burn P/H No. 1 | 85 | 18.4 | 13 | 57 | Alternative 21.4m3/s @ 82m head - 14.6MW - 64GWh |
| C56 | Ahuriri River – Hen Burn P/H No. 2 | 30 | 20.5 | 5.12 | 22 | |
| C57 | Hopkins River (3) | 30 | 34 | 8.5 | 37 | |
| C58 | Huxley River (3) | 55 | 9 | 4.1 | 18 | |
| C59 | Temple Stream (3) | 60 | 6 | 3 | 13 | |
| C60 | Waianakarua River (3) | 60 | 1.2 | 0.6 | 3 | |
| C61 | Kakanui River | 35 | 4.2 | 1.2 | 5 | |
| C62 | Meridian's Proposed Scheme | | | 200 | | Capacity between 200 – 250 MW |
| | Waitaki - d/s of Blackpoint (2) | | | | | ~360 MW, on the lower reaches, Details not known |

(1) Flows to achieve 50% pf.
(2) Locations not known
(3) Potentially within or near Department of Conservation land or Native Forest areas

## Appendix C: Maps

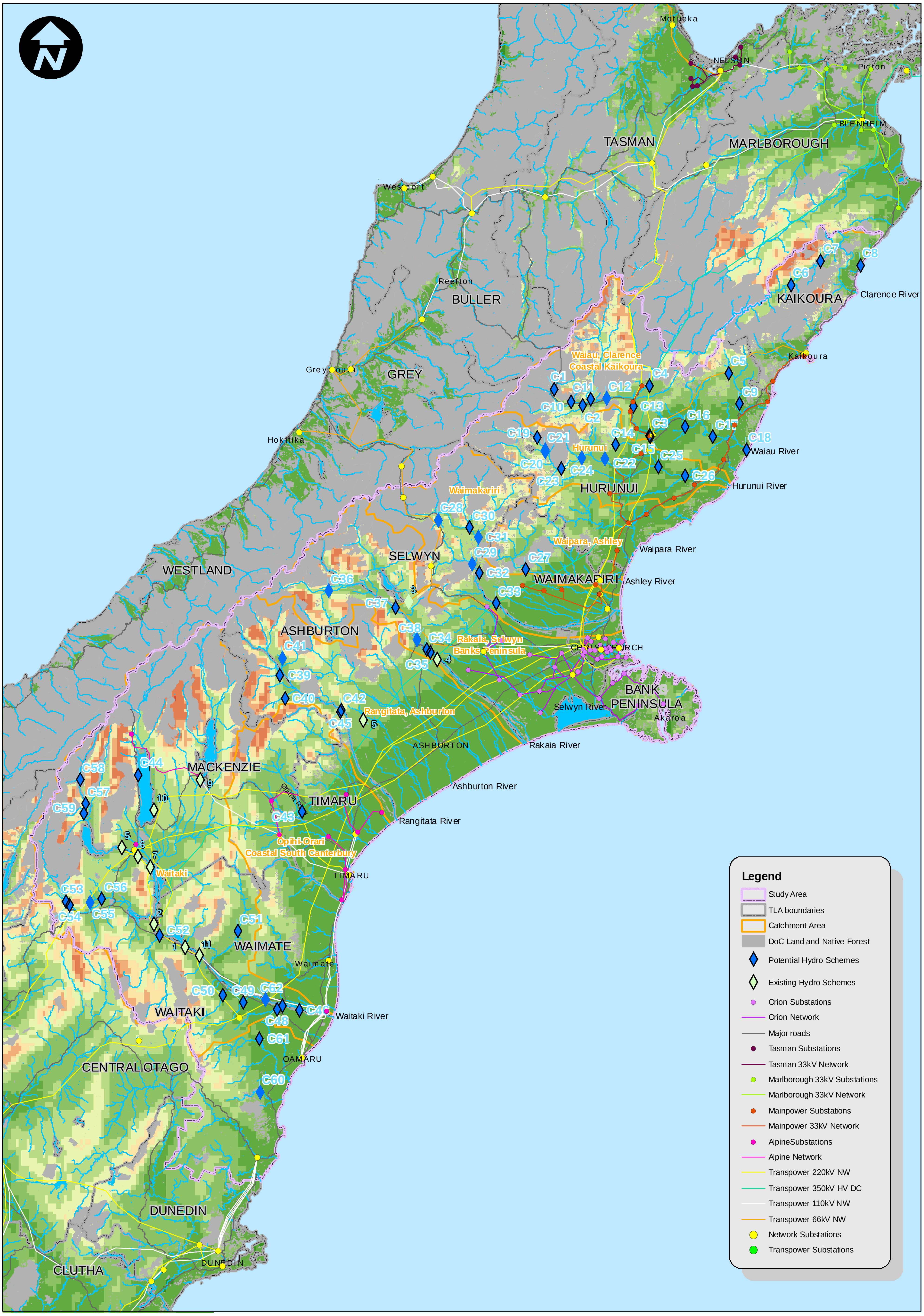
Map 1: Locations of previously identified hydro-electric schemes
(Waitaki to Hurunui) dated 8/06/06

Map 2: Potential Areas for Wind Farms plus areas of native forest.

Map 3: Canterprise Wind Map

Map 4: NIWA Wind Map

Map 5: NIWA Solar Radiation Map

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| | 13/07/06 | C.Utech |
| No | DATE | DRAWN |



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CLIENT EECA
PROJECT RREA: Canterbury

| DRAWN | DATE | REVIEWED PROJECT MNGR | APPROVED PROJECT DIR |
|---|---|---|---|
| CU | 08/06/06 | PJW | GU |
| DESIGNED SV | DESIGN REVIEW GM | | |

TITLE
Locations of previously identified hydro-electric schemes.

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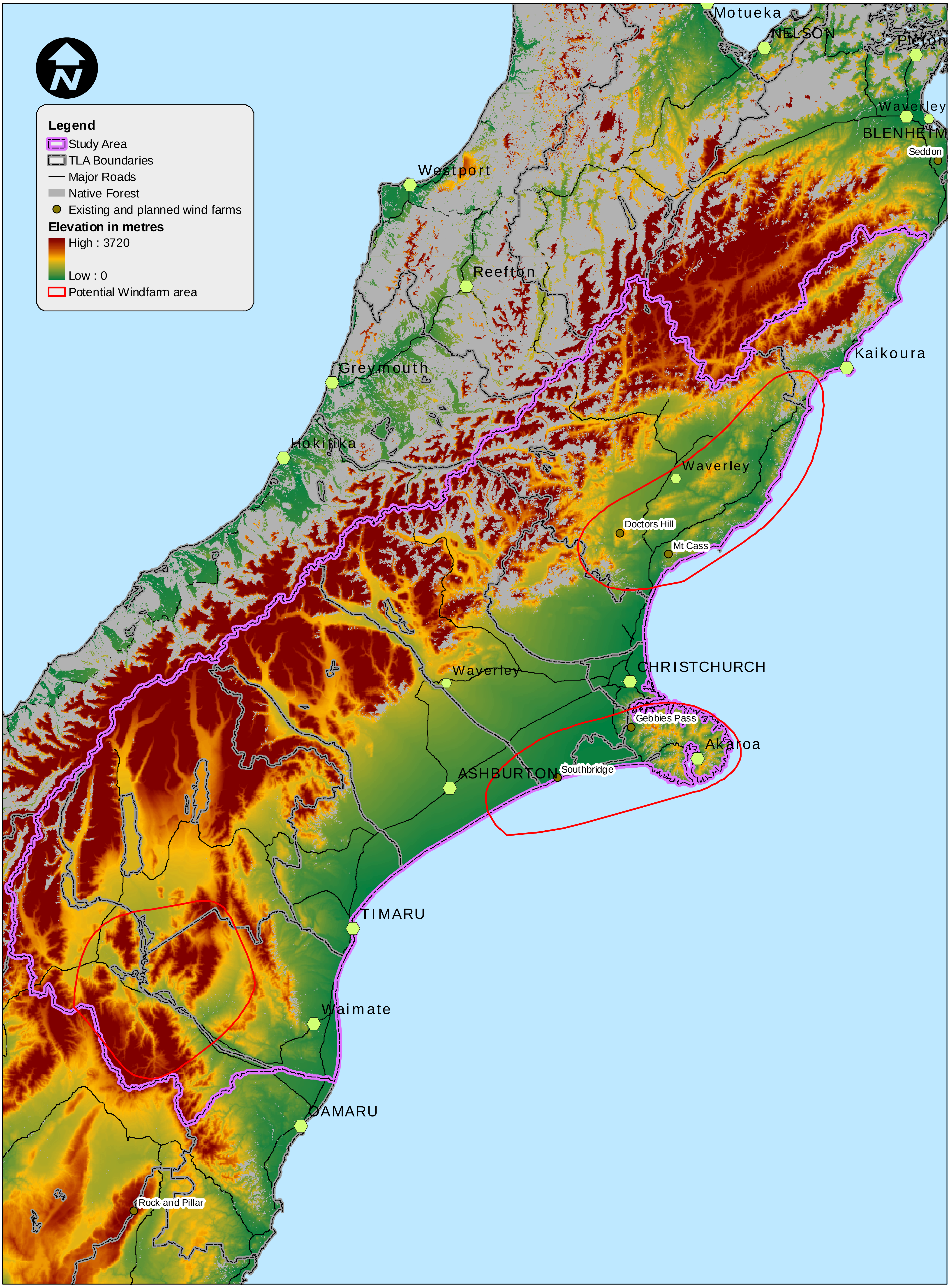


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| | 11/06/06 | C. Utech |
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|---|---|---|---|
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| PROJECT: RREA: Canterbury | | | |
| DRAWN: CU | DATE: 10/06/06 | REVIEWED PROJECT MNGR: P. White | APPROVED PROJECT DIR: G. Ussher |
| DESIGNED: CK | DESIGN REVIEW: CK | | |

TITLE
Potential Areas for Wind Farms plus areas of native forest.

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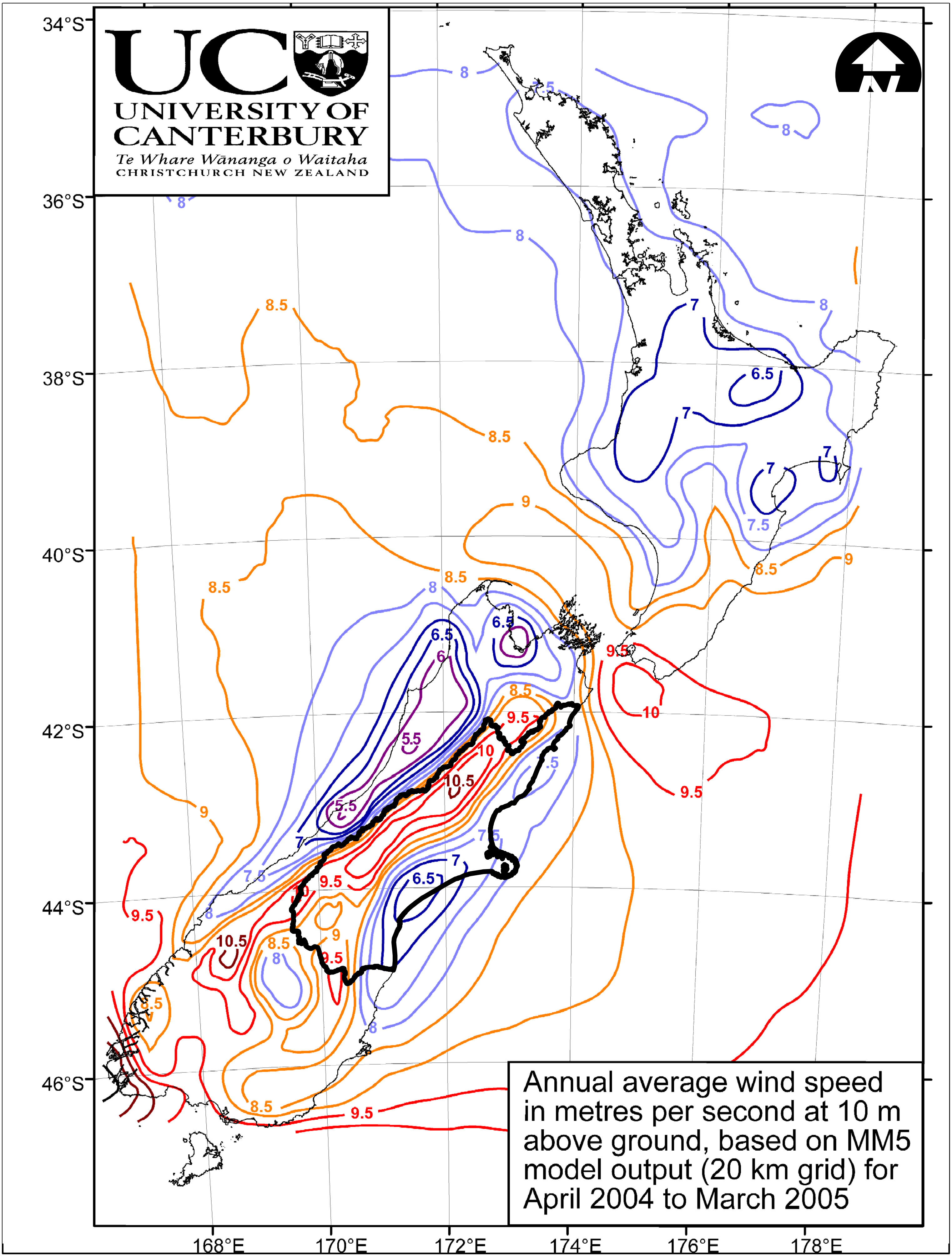


| No | DATE | DRAWN |
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| | 30/05/06 | C. Utech |

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|---|---|
| CLIENT | EECA |
| PROJECT | RREA: Canterbury |

| DRAWN | DATE | REVIEWED PROJECT MNGR | APPROVED PROJECT DIR |
|---|---|---|---|
| CU | 30/05/06 | P. White | G. Ussher |
| DESIGNED | DESIGN REVIEW | | |

TITLE

Canterprise Wind Map

Source: http://www.windenergy.org.nz/FAQ/resource.htm

| SCALE @ A4 | SKM PROJECT No | DRAWING No | AMDT |
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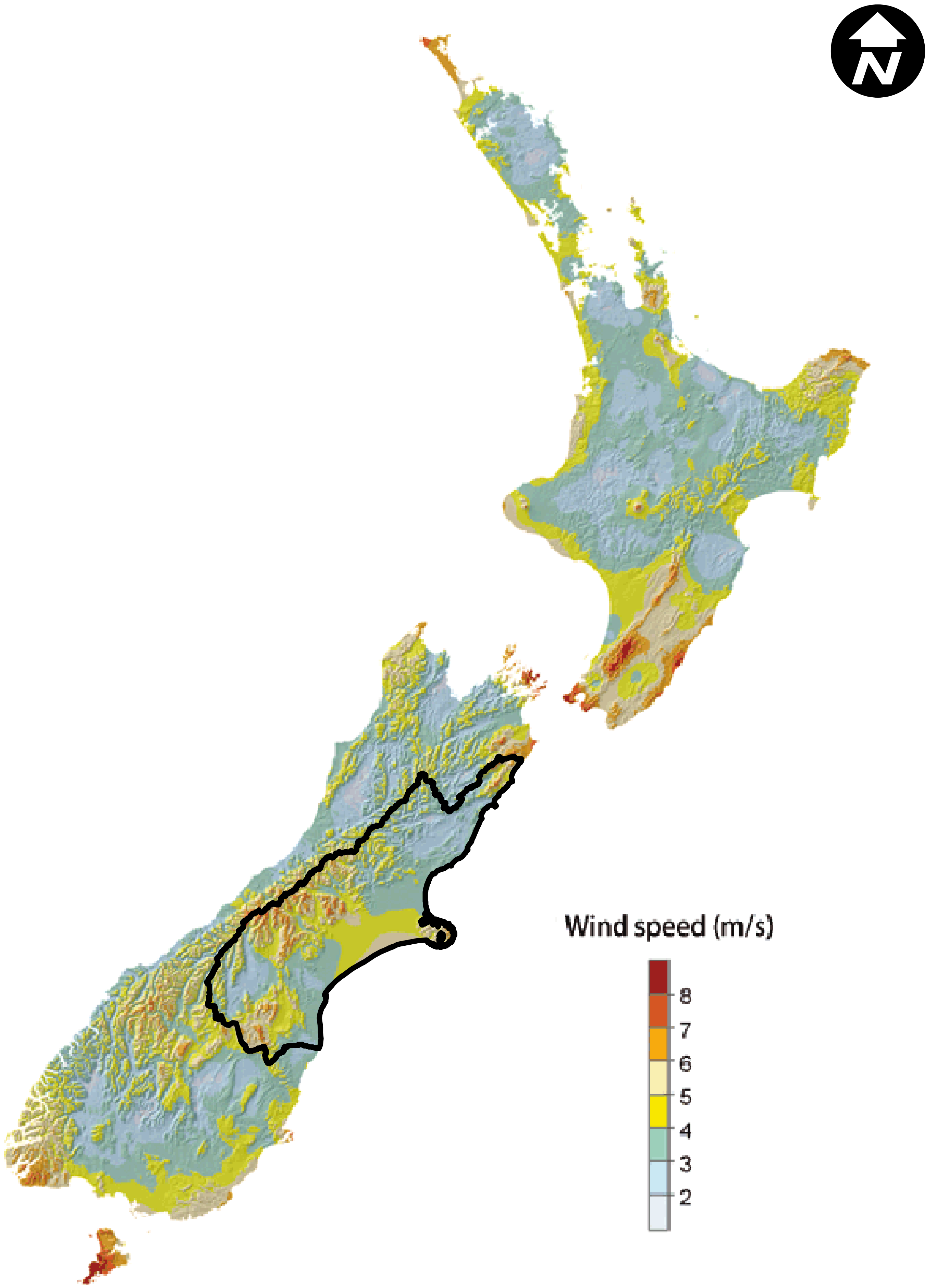
| 1:6,000,000 | AP01157 | Map 6 | |

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| CU | 30/05/06 | P. White | G. Ussher |
| DESIGNED | DESIGN REVIEW | | |

TITLE
## NIWA Wind Map
Source: http://www.niwascience.co.nz/pubs/wa/13-4/images/renewable3_large.gif/view

| SCALE @ A4 | SKM PROJECT No | DRAWING No | AMDT |
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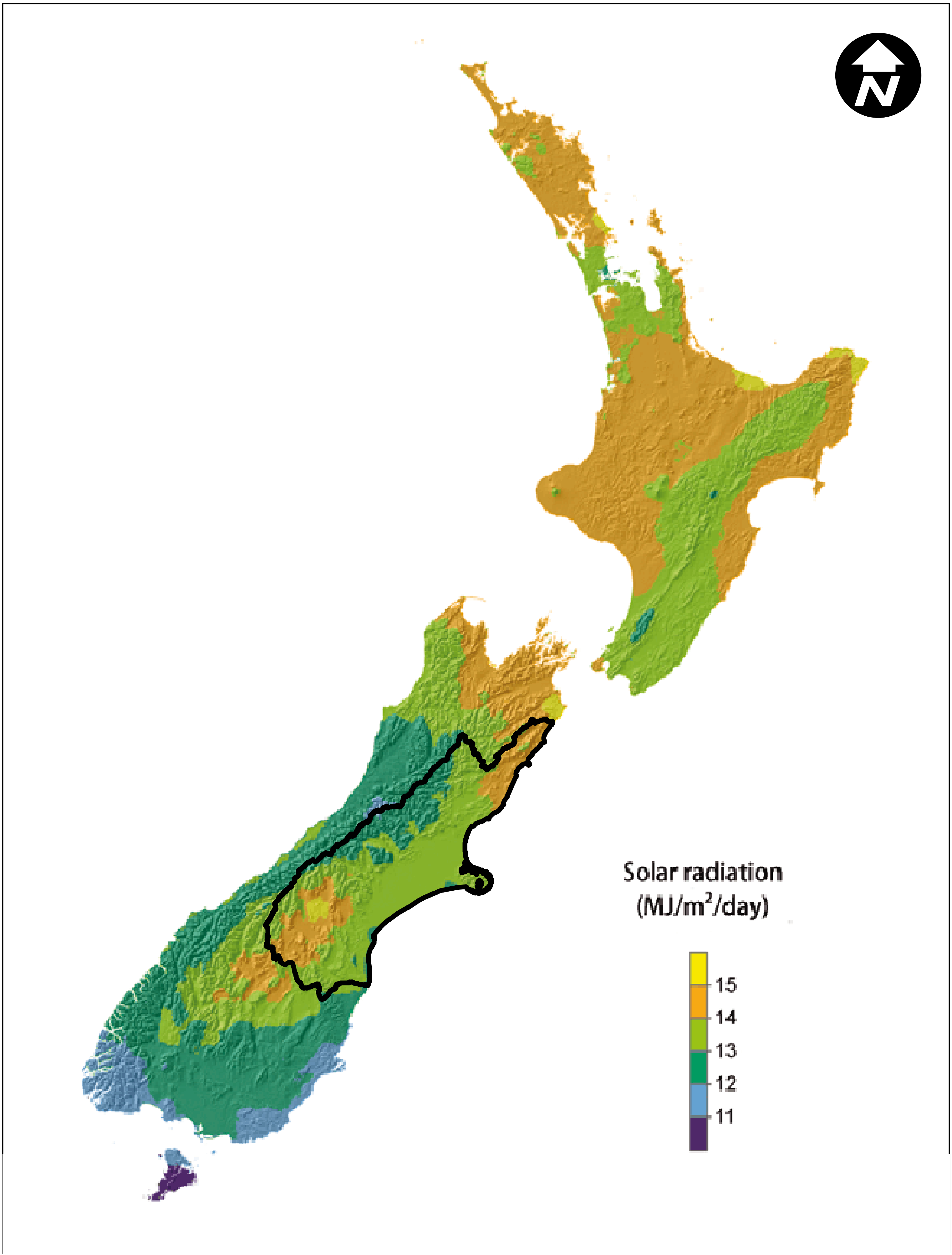


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| | 30/05/06 | C. Utech |

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CLIENT: EECA

PROJECT: RREA: Canterbury

| DRAWN | DATE | REVIEWED PROJECT MNGR | APPROVED PROJECT DIR |
|---|---|---|---|
| CU | 30/05/06 | P. White | G. Ussher |
| DESIGNED | DESIGN REVIEW | | |

TITLE

NIWA Solar Radiation Map

Source: http://www.niwascience.co.nz/pubs/wa/13-4/images/renewable4_large.gif/view

| SCALE @ A4 | SKM PROJECT No | DRAWING No | AMDT |
|---|---|---|---|
| 1:6,000,000 | AP01157 | Map 8 | |

## Appendix D: Proposed Wind Farms in New Zealand

| Site | Developer | Project capacity (MW) | Region | RMA application status | RMA application publicly notified |
|---|---|---|---|---|---|
| Awhitu | Genesis | 18 | Franklin | Consented after appeal but on hold | April 2004 |
| Titiokura | Unison/Roaring 40s | Up to 48 | Hastings | Consented after appeal | April 2005 |
| Hawkes Bay | Hawkes Bay Wind Farm | Up to 225 | Hastings | Consented after appeal | May 2005 |
| Taumatatotara | Ventus | Up to 20 | Waikato | Consented but on hold | |
| Motorimu | Allco Wind Energy | Up to 68 | Manawatu | Consented after appeal | August 2006 |
| Mahinerangi | TrustPower | Up to 200 | Clutha | Consented after appeal | November 2006 |
| Te Uku | Meridian Energy and WEL Networks | Up to 84 | Waikato | Consented after appeal (settled in mediation) | July 2007 |
| Kaiwera Downs | TrustPower | Up to 240 | Gore | Consented after appeal | November 2007 |
| Project Hayes | Meridian | Up to 630 | Central Otago | Consented but appealed | November 2006 |
| Taharoa | Taharoa C and PowerCoast | up to 100 | Kawhia | Consented but appealed | |
| Te Waka | Unison and Roaring 40s | Up to 102 | Hastings | Re-application called in to Environment Court | January 2006 |
| Waverley | Allco Wind Energy | Up to 135 | South Taranaki | Applied for consent, application on hold | October 2007 |
| Mill Creek | Meridian | Up to 71 | Wellington | Awaiting council decision on application | April 2008 |
| **Mt Cass** | **MainPower** | **Up to 69** | **Hurunui** | **Awaiting council decision on application** | **June 2008** |
| Project Central Wind | Meridian Energy | Up to 130 | Ruapehu and Rangitikei | Consented | July 2008 |
| Hauauru ma raki | Contact Energy | Up to 540 | Waikato | Called in to a Board of Inquiry, application publicly notified | September 2008 |
| Waitahora | Contact energy | Up to 177 | Southern Hawkes Bay | Application publicly notified | September 2008 |
| Weld Cone | Energy3 | Up to 1.5 | Marlborough | Application publicly notified | November 2008 |
| Mt Stuart | NZ Windfarms | Up to 6 | Clutha | Application publicly notified | December 2008 |
| Turitea | Mighty River Power | Up to 360 | Manawatu | Applied for consent | January 2009 |

| | | | | | |
|---|---|---|---|---|---|
| Slopedown | Wind Prospect CWP | | Southland | Not yet applied | |
| Maungatua | NZ Wind Farms | | Otago | Not yet applied – unlikely to proceed | |
| Puketiro | RES | | Wellington | Not yet applied | |

**Table xxx: Proposed Wind Farms in New Zealand**

# Appendix E: Renewable Energy Technologies including Small and Community Generation

This table provides in summary detail, a description, status, type of application, environmental effects and costs (2006) for each resource technology

## Table E1 Renewable energy technologies

| Resource / Technology | Technology Description | Technology Status | Type of Application<br>- size<br>- heat / electricity<br>- peak / base / capacity | Environmental Effects | Costs* |
|---|---|---|---|---|---|
| **Wind** | | | | | |
| Wind turbine | Extraction of kinetic energy from the wind flow<br>Horizontal axis wind turbine<br>2 or 3 blades<br>Direct drive or gearbox<br>AC generation | Well established<br>Commercially available | Large scale<br>Typical modern turbine size 2-3 MW<br>Wind farms up to 300+ MW<br>Intermittent generation<br>Capacity factor: 35-45%<br>Difficult to forecast | Visual impact<br>Noise<br>Shadow flickering<br>Electromagnetic interference | 1,700-2,100 $/kW (installed)<br>approx. 8 c/kWh<br>see comments above |
| Micro wind | Extraction of kinetic energy from the wind flow<br>Horizontal or vertical axis turbines<br>2 or 3 blades<br>Direct drive<br>DC generation | Well established<br>Commercially available | Small-scale (<10 kW)<br>Electricity generation or direct drive of water pumps<br>Intermittent generation<br>Difficult to forecast | Minimal visual and noise impact | 7,000-10,000 $/kW<br>30-40 c/kWh |
| **Solar** | | | | | |
| Solar Thermal System | Solar radiation transformed into heat<br>System consisting of solar collector and storage<br>Active systems use a pump whereas passive systems rely on gravitational forces | Well established<br>Commercially available | Small-scale, heat | Minimal visual impact | 3,000-6,000 $ per domestic system<br>11-17 c/$kWh_{th}$ |
| Solar Photovoltaic | Solar radiation transformed into electricity<br>Solar cells consisting of semiconductor material (either thick or thin technology)<br>Silicon most common semiconductor material | Well established<br>Commercially available | Small-scale, electricity<br>Intermittent generation | Minimal visual impact | grid connected (incl. inverter):<br>13,000-20,000 $/kW<br>approx. 80 c/kWh |

Source: SINCLAIR KNIGHT MERZ

| Resource / Technology | Technology Description | Technology Status | Type of Application<br>- size<br>- heat / electricity<br>- peak / base / capacity | Environmental Effects | Costs* |
|---|---|---|---|---|---|
| **Hydro** | | | | | |
| General | Water passing through a turbine rotates the runner which is harnessed to a generator to produce electricity. | | | | |
| Run of River | Divert part of river flows to power plant, may consist of small barrage or a weir to store little water at the water diversion area Often requiring tunnelling to move water to location where head drop can be achieved. | Well established<br>Commercially available | Small to medium scale electricity<br>Capacity Factor: 70-80% | Water extraction, aesthetic effects, ecological effects, recreational activities | 3,000-4,500 $/kW<br>4-7 c/kWh |
| Storage | Dam creates water storage upstream of the diversion to be used to generate power on demand | Well established<br>Commercially available | Medium to large scale electricity, peak load<br>Capacity factor 50-70% | Land inundation, effect on aquatic ecosystems (change in habitat, fish migration), water quality, soil erosion, recreational activities, noise | 3,500-5,000 $/kW<br>7-10 c/kWh |
| Pumped Storage | In addition to storage at the diversion area, water also stored at the downstream end where spent water is released and pumped back up to reuse it to generate. | Well established<br>Commercially available | Medium to large scale electricity, peak load | Land inundation, effect on aquatic ecosystems (change in habitat, fish migration), water quality, soil erosion, recreational activities, noise | 2,500-4,000 $/kW<br>generation costs: N/A (net consumer) |
| **Biomass** | | | | | |
| Direct heat | Biomass (such as woodwaste etc) is burnt to generate heat, either directly or as steam or hot thermal oil. | Well established<br>Commercially available | Available from the smallest domestic scale (wood stoves etc) to NZ's largest industries (pulp & paper). | Air quality may be affected by the smaller-scale developments. Large installations will have sophisticated emissions control systems. Fuel transport will have adverse effects. | Woody biomass:<br>4 $/GJ |
| Electrical generation | Biomass is burnt to generate steam for a power plant. | Well established<br>Commercially available | Economics favours the larger-scale developments, | Power plant developments will have sophisticated | 20 MW class woody biomass plant: |

Source: SINCLAIR KNIGHT MERZ

| Resource / Technology | Technology Description | Technology Status | Type of Application<br>- size<br>- heat / electricity<br>- peak / base / capacity | Environmental Effects | Costs* |
|---|---|---|---|---|---|
| | | | typically greater than 25 MWe, but limited by harvesting and transport costs.<br>Capacity factor: 90% | emissions control systems. Fuel transport will have adverse effects. | 3,400 $/kW<br>13 c/kWh |
| Liquid fuels | Very wide range of options for the production of liquid fuels, including hydrolysis and fermentation to ethanol, oil and tallow esterification to biodiesel, gasification and synthesis to methanol and hydrocarbons, pyrolysis etc). | Some technologies are well-established and commercially available (ethanol, biodiesel, etc), others are at prototype and/or early commercial stages (gasification and synthesis, pyrolysis, hydrolysis etc). | Economics favours the larger-scale developments, largely due to technical sophistication, but limited by distributed nature of the resource and the harvesting and transport costs. | Process plant developments will have sophisticated emissions and effluent control systems. Raw materials transport will have adverse effects. | Tallow and oils to biodiesel<br>Plant capacity 120,000 t/year. Plant capital cost $50 million. Feedstock cost $460/t, product cost $0.45/L.<br>Biomass to Methanol<br>Plant capacity 250,000 L/day. Plant capital cost $250 M. Product cost $1.1/L, $61/GJ<br>Biomass to Ethanol<br>Plant capacity 100,000 L/day. Plant capital cost $128 M. Product cost $1.75/L, $75/GJ |
| Gaseous fuels | Biological degradation (anaerobic digestion, fermentation etc) to generate methane gas. | Well established<br>Commercially available | Available from the smallest domestic and/or farm scale bio-digester to municipal effluent treatment for NZ's largest cities. | Process plant may need sophisticated effluent control systems. Raw materials transport may have adverse effects. | |
| **Geothermal** | | | | | |
| Conventional geothermal power plant (steam turbine) possibly with binary plant for steam condensing. | Fluid self-discharges from wells. Steam and liquid water flows are separated. Steam is passed directly through a turbine to generate electricity. Binary plant possibly used for condensing steam and heat recovery from hot | Well established<br>Commercially available, applicable to high temperature (typically >200°C) geothermal fields | Medium to large scale electricity (base load), plus downstream direct heat potential.<br>Capacity factor 90-95% | Air quality (especially $H_2S$ odour), impact on surface thermal features, shallow aquifers and ecosystems, noise, visual, subsidence, resource depletion | 2,500-3,000 $/kW<br>5 - 8 c/kWh |

Source: SINCLAIR KNIGHT MERZ

| Resource / Technology | Technology Description | Technology Status | Type of Application<br>- size<br>- heat / electricity<br>- peak / base / capacity | Environmental Effects | Costs* |
|---|---|---|---|---|---|
| | water. Waste fluids mostly reinjected into the ground. | | | | |
| Binary power plant on medium to low temperature resources | Wells may self-discharge or require pumping. Geothermal fluid heats a secondary (binary) fluid in a closed cycle that is vaporised, drives a turbine, is cooled and condensed. | Well established<br>Commercially available, most applicable to low temperature (120 to 200°C) geothermal fields. Applied in many USA fields usually with pumped wells. In NZ, binary plant presently only used for heat recovery from water on geothermal projects. | Small to large scale electricity (base load), plus downstream direct heat potential<br>Capacity factor 90-95% | Air quality (especially $H_2S$ odour), impact on surface thermal features, shallow aquifers and ecosystems, noise, visual, subsidence, resource depletion | 5,000-7,000 $/kW<br>7-10 c/kWh |
| "Enhanced" Geothermal systems (including Hot Dry Rock – HDR) | Geothermal reservoirs that have heat but insufficient water or permeability for conventional extraction. Multiple wells required for stimulating fractures and circulation of a fluid through injection-production well couples. Energy converted to electricity<br>Potential on margins of existing NZ fields. | At developmental stage in USA, Europe and Australia.<br>Large heat reserves in some geological environments, hence there is technology development effort. | Projects are likely to be large to enable economy of scale | Effects expected to be minimal compared to conventional geothermal.<br>Some thermal contraction effects (v minor subsidence) | High cost |
| Direct use of heat: many potential uses, including: | Paper manufacture<br>Timber drying<br>Other industrial processes<br>Space heating<br>Space cooling<br>Horticulture<br>Aquaculture<br>Bathing, spas | Well established<br>Commercially available technology exists for most applications. | Range from very small scale (domestic heat pumps) to large scale industrial plants<br>Capacity factor 90-95% | Depending on the scale of the operation, effects range from negligible to similar to a geothermal power plant | 300-400 $/kW$_{th}$<br>1-2 $/GJ |
| Ground source heat pumps | Heat pump using the ground or groundwater as a heat source or | Well established<br>Normally some measure of | Range from domestic to commercial building scale. | Minimal effects.<br>If using groundwater, then | Estimated $12,000 installation cost, higher than |

Source: SINCLAIR KNIGHT MERZ

| Resource / Technology | Technology Description | Technology Status | Type of Application<br>- size<br>- heat / electricity<br>- peak / base / capacity | Environmental Effects | Costs* |
|---|---|---|---|---|---|
| | sink. Can achieve very high efficiencies compared to conventional heat pumps using atmospheric heat sinks. Typically used to heat or cool buildings. | custom design in NZ, as there are few suppliers. Wider application in USA, Europe, Japan and China. | | affects water temperature. | standard heating-cooling systems. Electrical input at 25-30% of output.<br>Viable for commercial buildings if long term efficiency is considered. |
| **Tidal (Kinetic Energy)**<br>**Ocean Current** | Exploitation of velocity component of tide. Flow of water passing turbine blades cause aerodynamic lift. Blades are connected via shaft to electrical generator | | | | |
| Technology a1 | Similar operating principle to vertical axis wind turbine. 2 or 3 blades mounted on a monopole seabed foundation | Large scale 300KW prototype demonstration 3 year sea deployment nearing completion.<br>1000KW grid connected demonstration prototype planned 2006-2007 | In the order of 1MW per installation<br>Electricity production<br>Base load contributor – Energy BUT source intermittent but highly forecastable (years in advance)<br>Capacity factor 40-50% | Yet to be fully understood but generic issues with:<br>Sub sea noise especially in piling operations<br>Marine mammal collision<br>Risk to marine navigation and associated pollution risks<br>Underwater cabling<br>-Seabed and habitat disturbance<br>-Electromagnetic interactions with elasmobranchs | Based upon estimates rather than track record:<br>Early full scale prototypes<br>14,000 to 23,000 $/kW<br>Cost of energy range of<br>28-43 c/KWh<br>Early production models<br>5,000 $/kW<br>Cost of energy<br>approx. 22 c/KWh |
| Technology a2 | As above but floating Vertical axis rotary device on mooring. Either fully submerged or surface piercing. | Number of 500KW grid connected demonstration prototypes planned 2006-2007 | In the order of 1MW per installation<br>Electricity production<br>Base load contributor – Energy BUT source intermittent but highly forecastable (years in advance) | As above minus piling issue | as above |

Source: SINCLAIR KNIGHT MERZ

| Resource / Technology | Technology Description | Technology Status | Type of Application<br>- size<br>- heat / electricity<br>- peak / base / capacity | Environmental Effects | Costs* |
|---|---|---|---|---|---|
| | | | Capacity factor 40-50% | | |
| Technology a3 | Ducted turbine mounted on seabed via concrete foundation | 1MW grid connected prototype demonstration planned 2006-2007 | In the order of 1MW per installation<br>Electricity production<br>Base load contributor – Energy BUT source intermittent but highly forecastable (years in advance)<br>Capacity factor 40-50% | As above minus piling issue | as above |
| Technology a4 | Reciprocating aerodynamic foils convert mechanical motion into hydraulic rams power take off device. | 100KW grid connected demonstration planned 2007 | In the order of 1MW per installation<br>Electricity production<br>Base load contributor – Energy BUT source intermittent but highly forecastable (years in advance)<br>Capacity factor 40-50% | As above minus piling issue | as above |
| **Tidal (Head)** | Exploitation of head differential between high and low tide. | | | | |
| Technology b1 | Impoundment (dam) of estuary. Gates within the dam allow water to pass upstream of structure. Closure of gates at high tide creates head height differential across dam as tide falls on downstream side. Operation reversed at low tide. Low hydro | Well established<br>Commercially available technology exists for most applications. | In the order of 100MW per installation<br>Electricity production<br>Base load contributor – Energy BUT source intermittent but highly forecastable (years in | Profound and irreversible change in estuary eco-system | Existing plants are broadly comparable with the upper end of fossil fuel based generation costs<br>Costs are expected to be much higher in NZ due to the lower tidal range. |

Source: SINCLAIR KNIGHT MERZ

| **Resource / Technology** | **Technology Description** | **Technology Status** | **Type of Application**<br>**- size**<br>**- heat / electricity**<br>**- peak / base / capacity** | **Environmental Effects** | **Costs*** |
|---|---|---|---|---|---|
| | turbines may then be used to release head and generate electricity. | | advance) | | Minimum tidal range currently considered economic for this technology is considered 5m. |
| Technology b2 | Narrow headlands create 'nature' impoundment as head height can vary across the sides of the land mass. The introduction of piping containing water turbines exploits head driven flow. | Yet to be demonstrated at meaningful scale | In the order of 100MW per installation<br>Electricity production<br>Base load contributor – Energy BUT source intermittent but highly forecastable (years in advance) | Hazard to fish life passing through pipe.<br>Estimated to be little eco-system impact | unknown |
| **Wave** | | | | | |
| Technology a | Oscillating water column:<br>Conversion of wave energy into pneumatic energy, channelled through bi-directional air turbine connected to rotary electrical generator.<br>Can be configured as floating structure, seabed fixed or fashioned into cliffs or breakwaters | Demonstrated at 500KW grid connected site. Presently with 4 year of operational service | Intermittent energy source. Forecast ability better than wind, but good reliability only based on future time period estimates of 6-8 hrs.<br>Electrical generation<br>500-1500's KW size range per installation<br>Capacity factor 40% | Yet to be fully understood but generic issues with:<br>Marine mammal collision<br>Risk to marine navigation and associated pollution risks (less if deeply submerged<br>Changes in sediment transportation patterns<br>Underwater cabling:<br>-Seabed and habitat disturbance<br>-Electromagnetic interactions with elasmobranchs | Based upon estimates rather than track record:<br>Early full scale prototypes<br>11,000 to 26,000 $/kW<br>63-72 c/KWh<br>Early production models<br>7,000 $/kW<br>approx. 29 c/KWh |
| Technology b | Point Absorber:<br>Conversion of wave heave motion into mechanical relative displacement between floating | Demonstrated at up to 100(?)KW power level in open sea | Intermittent energy source. Forecast ability better than wind, but good reliability only based on future time | Yet to be fully understood but generic issues with:<br>Marine mammal collision<br>Risk to marine navigation | as above |

Source: SINCLAIR KNIGHT MERZ

| **Resource / Technology** | **Technology Description** | **Technology Status** | **Type of Application**<br>**- size**<br>**- heat / electricity**<br>**- peak / base / capacity** | **Environmental Effects** | **Costs*** |
|---|---|---|---|---|---|
| | buoy on sea surface and other reference point. Variety of PTO options including;<br>Fluid pumping (water or oil)<br>Hose Pump<br>Direct drive linear generator | | period estimates of 6-8 hrs.<br>Electrical generation + high pressure water pumping/desalination opportunities<br>100's KW size range per installation<br>Capacity factor 40% | and associated pollution risks (less if deeply submerged<br>Changes in sediment transportation patterns<br>Underwater cabling<br>-Seabed and habitat disturbance<br>-Electromagnetic interactions with elasmobranchs | |
| Technology c | Overtopping:<br>Use of wall to focus wave energy into central location. Waves of certain size break over head wall and fill floating reservoir. Low head hydro turbines in floor of reservoir are connected to rotary electrical generator(s) | Demonstrated at up to 100KW level in open sea. Advance plans in place to deploy MW size device in 2007 | Intermittent energy source. Forecast ability better than wind, but good reliability only based on future time period estimates of 6-8 hrs.<br>Electrical generation<br>10's MW size range per installation<br>Capacity factor 40% | Yet to be fully understood but generic issues with:<br>Large mammal collision<br>Risk to marine navigation and associated pollution risks (less if deeply submerged<br>Changes in sediment transportation patterns<br>Underwater cabling<br>-Seabed and habitat disturbance<br>-Electromagnetic interactions with elasmobranchs | as above |
| Technology d | Attenuator:<br>Semi-submerged, articulated structure of sections linked by hinged joints. The wave motion on these joints is resisted by hydraulic rams, which pump high-pressure oil through hydraulic motors which | 750KW pre production prototype deployed. Commercial order placed for several devices for Portuguese deployment 2006. | Intermittent energy source. Forecast ability better than wind, but good reliability only based on future time period estimates of 6-8 hrs.<br>Electrical generation<br>10's MW size range | Yet to be fully understood but generic issues with:<br>Marine mammal collision<br>Risk to marine navigation and associated pollution risks (less if deeply submerged | as above |

Source: SINCLAIR KNIGHT MERZ

| **Resource / Technology** | **Technology Description** | **Technology Status** | **Type of Application**<br>**- size**<br>**- heat / electricity**<br>**- peak / base / capacity** | **Environmental Effects** | **Costs*** |
|---|---|---|---|---|---|
| | drive electrical generators | | 1-2MW size range per installation<br>Capacity factor 40% | Changes in sediment transportation patterns<br>Underwater cabling<br>-Seabed and habitat disturbance<br>-Electromagnetic interactions with elasmobranchs | |

*Sources: General experience of SKM and NaREC gained in a number of different renewable energy projects

EHMS 2005 for solar thermal costs

## Appendix F: Meridian Energy Publication (2009 update):Choices

In 2006 Meridian published “Options Choices Decisions: Understanding the options for making decisions about New Zealand’s electricity future” (Choices). The purpose of this document was to provide an objective perspective on the issues facing the industry and possible futures for the New Zealand wholesale electricity market. Choices was Meridian’s contribution to providing quality information needed for making good decisions in the sector.

This 2009 document updates some of the key parts of Choices in light of major energy sector developments over the past two years. It provides an updated view of the project economics of new generation options for New Zealand. It also discusses the performance of the wholesale market over its twelve year history. Like the original Choices report, it is hoped this 2009 update is a valuable input into everyone’s understanding of the issues facing New Zealand’s wholesale electricity sector.

*See the 2006 Choices publication for a fuller review of the technology options covered in brief in this report. The 2006 report also covers in detail demand side options for meeting electricity demand growth, including energy efficiency and micro generation. The reports are available on Meridian’s website:* www.meridianenergy.co.nz/AboutUs/Reports/